The AMSAT Journal

Incorporating the AMSAT Newsletter

Volume 14 No. 1 January 1991

Editor: ***Joe Kasser, G3ZCZ***

Managing Editor: ***Robert M. Myers, W1XT***

The Past, The Present and The Future

An Editorial By AMSAT President Doug Loughmiller, KO5I

1991 marks the 30th anniversary of the launching of OSCAR 1. It is safe to say the Amateur Satellite Service has come a long way in the 30 year period of time since the events of that historic day in 1961 when Amateur Radio made its way into the environs of space for the first time.

From the very first steps it became apparent the marriage between Amateur Radio and space was an ideal one, destined for a long and fruitful relationship. The pride and excitement, generated by the Project OSCAR crew and their bold endeavor to put Amateur Radio into space, fueled a strong commitment from yet additional Radio Amateurs to insure that Amateur Radio would return to space at every opportunity we could collectively muster. To this day that fact is still being proven out.

A prime example is the events of 1990. The successful launching of seven Amateur satellites has been well documented both in the pages of this *Journal* and various other Amateur Radio periodicals. The advent of these new birds will have a long lasting impact upon our hobby.

In addition, after a five year absence, Amateur Radio activity returned aboard the Space Shuttle Columbia as long time AMSAT member Ron Parise, WA4SIR, activated the on-going SAREX payload during the STS-35 ASTRO-1 mission in early December. Ironically, within a matter of a few hours of the Columbia launch another AMSAT member, Musa Manarov, U2MIR, journeyed back into space with the anticipation of yet further Amateur operations from aboard the Soviet Space Station Mir.

And the story continues....

While these subjects made their way into the headlines of the Amateur Radio press, other equally significant events quietly took place that will undoubtedly have an impact upon the Amateur Satellite Service as well. Probably the most significant of these events took place during the AMSAT Board of Directors meeting in Houston, Texas over the weekend of October 19th.

For me at least, it was a bittersweet situation. Sometimes the AMSAT Board of Directors have a difficult job. This was one of those times. For several years the organization had been studying and evaluating the prospects of taking on a geosynchronous satellite project to be dedicated solely to Amateur Radio applications. Many man hours of effort had been applied to the project. It was no doubt a worthwhile endeavor, but the question that had to be dealt with had to do with whether it was a practical and obtainable objective or not.

Sitting in on my first BOD meeting as a voting Director I was seated across the table from my esteemed colleague Jan King, W3GEY. Jan is a man I respect greatly. Over the past couple of years Jan and I had worked closely together in trying to find ways to make the Phase IV concept, as it had become known, a workable proposition for Amateur Radio. Jan is, among other things, a man of vision and the vision he held for this concept, the next logical step in the evolution of OSCAR satellites, was so strong that it had inspired many of us to strive in every way possible to make this vision a reality. The Phase IV project was Jan's idea. He had put a great deal of thought into the proposed satellite system and its potential applications. More than anything I wanted to see us turn another one of Jan's visions into reality but this time it wasn't as simple as it had been before. This wasn't the first time we had contemplated turning a vision into a reality, but it was the first time we had considered the metamorphosis of a vision of this magnitude.

What had to be said that weekend did not come as any surprise to those of us who have responsibility for moving the organization forward. It might, however, have come as a surprise to many of the members and because of this fact it needed to be addressed and debated among the entire board one final time.

Over the past year or so it had become increasingly apparent that the Phase IV project simply didn't have the level of support from within the Amateur community needed to insure that we could see it through to fruition. The biggest obstacle that lay ahead of the project could be summed up into a single word — money. In the final analysis, at this point in time, we couldn't afford to tackle such an ambitious project. While AMSAT has been successful at funding projects at the tens of thousands of dollars level and moderately successful at funding projects at the hundreds of thousands of dollars level, we simply have no reason to believe that we could "step out on faith" as we have in the past and tackle a project in the multi-million dollar level hoping that the money would trickle in after we had committed to the project. This project is simply too vast and demanding to be approached in this fashion.

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AMSAT-NA
850 Sligo Ave.
Silver Spring, MD 20910

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The AMSAT Journal Staff

Editor: Joe Kasser, W3/G3ZCZ
Managing Editor: Bob Myers, W1XT
Advertising: Doug Loughmiller, KO5I
Circulation: Martha Saragovitz

Editorial Office: 11421 Fairoak Drive; Silver Spring, MD 20902. Telephone (301) 593-6136 (8-10 p.m. eastern). **Use this phone number for *Journal* related topics only.**

Production Office: 18 McBride Road, Litchfield, CT 06759. Telephone/FAX (203) 283-0769.

Advertising Office: Post Office Box 247, Brookston, TX 75421. Telephone (903) 784-3740. FAX (903) 784-3871.

AMSAT-NA Headquarters: 850 Sligo Avenue, Suite 600, Silver Spring, MD 20910-4703. Telephone (301) 589-6062 (9 a.m. -5 p.m. eastern). FAX (301) 608-3410.

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So it was with this in mind, following months of efforts to try to elicit the type of support needed from the Amateur Radio community at large, the AMSAT Board of Directors voted unanimously to terminate the Phase IV geosynchronous satellite program. While this is still a noble and worthwhile cause, now is clearly not the time to tackle such an ambitious project. I must admit that this was a painful decision for me to make personally. Killing a vision, particularly the vision of someone you respect, is not a pleasant task. But it was the only decision we could render given the set of circumstances we had to work with.

If we're not going to pursue a Phase IV satellite, then what are we going to define as our next major satellite initiative? Well, as I said this was a bittersweet occasion. Having taken the bitter pill of terminating such an exciting program we were fortunate to have a sweet lump of sugar in the form of an equally exciting project to now set our sights on.

It goes without saying, many of us had been giving a great deal of thought to this issue long before we got to Houston. In fact, as we began to understand our limitations in doing the Phase IV project several of us including Jan, Bob McGwier, N4HY, Dick Jansson, WD4FAB, Dick Daniels, W4PUJ, and I began to turn our attention to another interesting and worthwhile project. This

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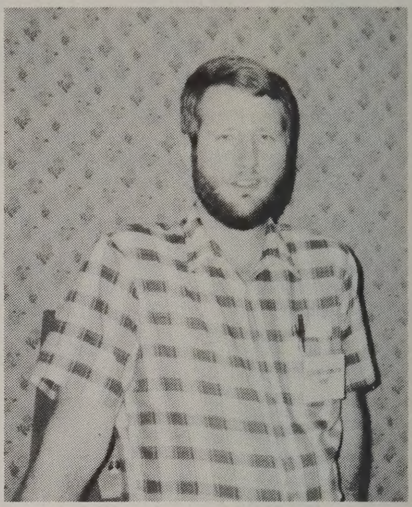
1990 AMSAT Space Symposium and Annual Meeting

By Drew Deskur, KA1M
VP Special Projects
and
Courtney Duncan, N5BF
VP Operations

The Johnson Spaceflight Center (JSC), outside of Houston, TX was the setting for the 1990 AMSAT Space Symposium and Annual Meeting. The event was sponsored by the Johnson Spaceflight Center Amateur Radio Club (W5RRR) and by all accounts, the weekend was an overwhelming success. The meeting, held on October 19-21, 1990, was attended by over 300 Radio Amateurs and others interested in the Amateur Space Program from all over the world.

The wide range of topics presented is indicative of how the Amateur Space Program has expanded and matured. Presentation topics ranged from "How to Get Started in Amateur Satellites," presented by Keith Pugh, W5IU, to an exhaustive presentation given by Tom Clark, W3IWI, describing the use of a super-computer to study the orbit of AMSAT-OSCAR 13 (AO-13). In many ways the Amateur Space Program has become a world of its own, with interests mirroring the range of interests in the world of Amateur Radio.

The topics presented were so numerous that presentations were made on all three days of the Symposium (a first for AMSAT Symposiums). Friday saw Jeff Wallach, N5ITU, describe Satellite Image Processing to a Standing Room Only crowd. Over 100 people were jammed into a room designed for 50 to find out that the jump from their existing OSCAR station to a station capable of receiving Weather satellite images was not all that great. Following Jeff's talk, Dick Campbell, N3FKV, described what was involved in the management and upkeep of the AMSAT Orbital Data information (Keplerian elements) he publishes

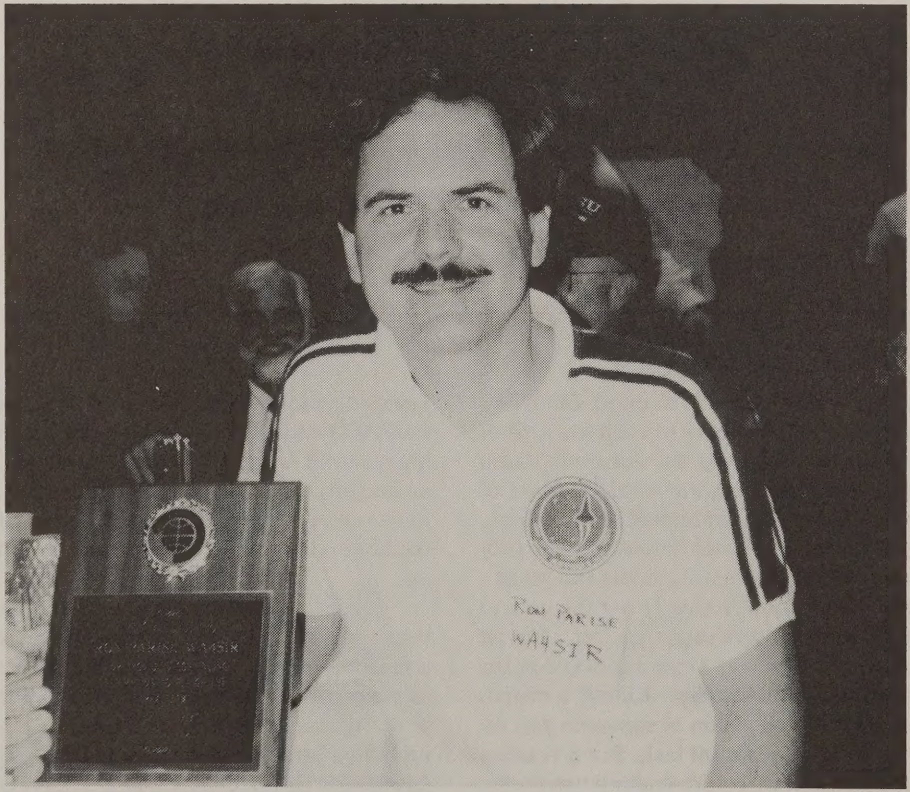


AMSAT Vice President of Operations Courtney Duncan, N5BF, enjoys a quiet moment between activities during the AMSAT Annual Meeting.

weekly through the AMSAT News Service.

Friday was an opportunity to meet old friends as well as make new ones. There was an AMSAT Hospitality Suite at the hotel which proved to be a popular place to finally put faces to the voices heard on the birds. In addition to the Hospitality Suite, the AMSAT Engineering team met with the PACSAT Command Station team to discuss what development work was left to complete prior to pronouncing the Microsats operational. One attendee flying to Houston from the Boston area got to the airport Friday afternoon to find his flight to Hobby Airport (close to JSC) was cancelled. The only way to get into the Houston area that night was to take a flight to Intercontinental Airport (which is on the other side of Houston) and then he would have to rent a car or hire a taxi for the 1+ hour ride from Intercontinental to JSC. While settling into his aircraft seat he struck up a conversation with one of the other passengers and discovered that he was also going to the Symposium and had already planned to rent a car. That was certainly a great way to start the weekend.

Activities on Saturday started early with a Command Station Development Program Breakfast. Presentations began at 8:00 am in the Visitor Center Auditorium. AMSAT President and General Manager Doug Loughmiller, KO5I, acted as MC during the day's presentations. Each of the presenters were well prepared and after each talk, the presenter would have a small group of people who would follow him off for further questions about that specific topic. An 80 page proceedings of the Symposium has been published and copies of the proceedings are still available from AMSAT Headquarters in return for a dona-



Shuttle Astronaut Dr. Ron Parise, WA4SIR, was recognized during the AMSAT Annual Meeting for his efforts in support of the Shuttle Amateur Radio Experiment (SAREX) which he operated during the STS-35 mission aboard *Columbia* in early December.

tion of at least $20.

As always, deciding between the different interesting talks on various aspects of the amateur satellite program and the informal sessions held in and around the hotel wherever groups of like-minded enthusiasts found themselves together was a difficult decision to make, a choice which was even worse this year. Tours of JSC, which could easily consume an entire weekend in themselves, also competed for the attention of the attendees. In addition to the technical presentations and tours, a working amateur station was available right outside the meeting hall. The W5RRR club permanently maintains a demonstration class satellite station in the main visitor exhibit building (Building 2). PACSAT (AO-16) demonstrations and AO-13 contacts were conducted from this station during the Saturday sessions. All of the presentations and deliberations were important. After all, this is the one time in a given year when AMSAT members and leaders are able to get together for a few days of intensive interaction.

Some of the Saturday presentations were focused on late-breaking developments in a number of areas. Status reports on the Microsats as well as a report of the AO-13 orbit study drew many inquiries during the Q&A session. Ron Parise, WA4SIR, whose talk was originally scheduled to be a review of the SAREX on STS-35, was presented as a pre-view of his mission. Lou McFaddin, W5DID, copresented with Ron and explained the process AMSAT and W5RRR had to go through to propose the SAREX to NASA administration. Lou also brought some of the hardware that will fly on the STS-37 launch, scheduled for the spring of 1991, which will carry a crew entirely composed of Hams (who also happen to be Astronauts and Mission Specialists).

In addition to presentations on existing satellites, there were talks given on proposed satellites. Karl Meinzer, DJ4ZC, spoke on the results of the Phase-IIID kickoff meeting. This will be another international development effort, which plans to place into an orbit similar to AO-10 and AO-13, a satellite with greatly improved uplink and downlink performance (10 dB or greater on 435 MHz and higher). Along with the Phase III-D presentation, four other satellite programs were being proposed during the Symposium, three of which were sponsored by Universities. Programs such as these could become an excellent proving ground for budding spacecraft developers.

Saturday evening found the Symposium attendees at the AMSAT Annual Meeting held at the JSC Employee's Recreation Center. Conversations and discussions started during the afternoon talks continued into the now famous Attitude Adjustment Hour which preceded the Family Style Texas Bar-B-Que. After dinner, William Huffstetler, NASA's Head of New Initiatives at JSC, presented a keynote speech and spoke highly of AMSAT's accomplishments and plans for the future. Awards were presented to AMSAT Volunteers who have been outstanding in the efforts they have expended on AMSAT's behalf. A few awards of note were Lou McFaddin, W5DID, Bill Tynan, W3XO, and Rosalie White, WA1STO, for their work on SAREX as well as Franklin Antonio, N6NKF, who received a standing ovation for his work as the author of InstantTrack, the popular tracking program.

As informal discussions between members went late into the night, Sunday morning came all too early. Field Opera-

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A number of individuals were recognized for their contribution to the SAREX Project. Here Lou McFadden, W5DID, (left), is shown making a presentation to Charlie Cottle of the Lockheed Engineer and Science Company Fabrication Shop in recognition of the work done in preparing the SAREX hardware for flight. (KO5I Photo)

Evelyn Garrison, WS7A, National Marketing Manager for ICOM presents AMSAT President Doug Loughmiller, KO5I, with an ICOM 275A 2-meter multimode transceiver to be awarded as the grand prize. AMSAT wishes to extend its sincerest thanks to Evelyn and ICOM for this most generous donation. (KA1M photo)

The Past, The Present and The Future

(Continued from page 3)

Project, known as Phase IIID had been openly discussed by a number of international groups over the past several months including our colleagues of long standing at AMSAT-DL. In anticipation of our potential participation in this project last Spring Ron Broadbent, G3AAJ, of AMSAT-UK and I traveled to Marburg, West Germany for preliminary discussions with AMSAT-DL President Karl Meinzer, DJ4ZC. A little over a month later, a small contingent of technical representatives from within AMSAT-NA travelled to Marburg to participate in the first "experimenters meeting" of the Phase IIID project. This meeting has been reported on in the pages of previous *Journals*. A follow up meeting is now scheduled for May of this year.

While this project has been tagged as a Phase III satellite project and while one of the potential orbits the satellite may be placed in is a Molyna type of orbit, this label is a little misleading. The mission objectives and engineering design parameters are yet to be fully defined. In general terms however, this mission is planned to be a super enhanced Amateur satellite. Improved link performance, transponder management and attitude control are but a few of the considerations being given to improving the communications capability of this satellite system. It, too, will be an ambitious project but because of the world-wide communications capability it will offer over a geosynchronous payload, the burden sharing in developing such a satellite can be spread over groups the world over as opposed to groups of only part of the world as would have been the case with a Phase IV geosynchronous bird.

Following a presentation by Karl Meinzer and lengthy discussion by the AMSAT Board of Directors and Officers, the AMSAT Board voted unanimously to adopt this internationally based project as the next major satellite construction program AMSAT-NA will pursue. Specific details about the mission will be published in future articles here in the *Journal*.

As we move ahead with this project it is important that the membership be kept informed about both the progress and the needs of the mission. I can assure you, we will strive to fulfill this requirement. Further, over the past several months, many of you have voiced opinions and concerns about our future satellite construction activities both in terms of frequencies to be used and the modes of operation to be supported. I can assure the membership these messages have been received loud and clear by the AMSAT Board of Directors. It is our intent to see that the will of the membership be fulfilled. We are always interested in hearing from you. Feel free to write to me at the address listed at the front of the *Journal*. In the coming months, I will be sharing insights with you about both our quest to keep Amateur Radio in space and issues related to the goals and objectives of our organization. Until then, 73. See you on the birds! ■

News: From Russia with ....

Pat Gowen, G3IOR @ GB7VLS
17 Heath Crescent,
Hellesdon, Norwich, Norfolk NR6 6XD
England

Club Station RK3KP

Leo Labutin, UA3CR, who recently returned home from meetings with DB2OS, DFØRR, DL1CF, DJ2EV and the Ricofunk Company reported that he had purchased a lot of new Amateur Radio gear for the Adventure Club and for upgrading RK3KP .

The RK3KP club station is situated in the Centre of Science and Technology for Youth. As with many Amateur stations it is allocated a room located just under the roof of the house. Their small room is now well equipped with HF, VHF and Satellite modules, and also holds the command station for the Radio-M-1 satellite and the 24hr/day active RK3KP HF BBS.

A second large room is for education purposes, and now has three terminals: IBM PC -AT + TNC-2 + VHF Radio. The terminals are for training young people between the ages of 12 and 16 years to study Packet Radio and mailing to the main BBS RK3KP.

At this time they are trying to get from their 'FCC', the Ministry Communication of the USSR, up to ten calls allocated as RK3KPA, KPB, KPC ...etc.

Lectures on Satellite and Packet are covered by Eugeny, RA3APR (Leo's Son), Galina, UA3DSP, and by Leo, UA3CR, himself. Leo says, " Our Amsat-U-Sputnik group is a new independent form of USSR Amateur Radio organization, with no links with DOSAAF."

SALYUT-7

Further to my forecast of the re-entry between late December 1990 and early March 1991 of the large SALYUT-7 space station, Nico, PAØDLO reports "SALYUT-7 is definitely coming down. There is no fuel on board the old station. The orbit cannot be changed anymore. Also the attitude of the complex cannot be changed. Since it is tumbling now, it is impossible to dock another spacecraft, like a Progress, to the station. As the Soviets have lost control over the station completely, they have given it up and await its decay without being able to influence it at all".

An extra module, COSMOS-1686 (frequency 19.955 MHz) which was docked to SALYUT-7 now seems to have separated. Because of the big mass of the station, we may certainly expect parts of the station (of up to a few hundred kilograms!) to reach the Earth's surface. Obviously, because of the inclination, this debris can only come down between 51.5 degrees north and 51.5 degrees south latitude. Although the numbers vary a lot, I now expect the decay sometime in January 1991.

SALYUT-7 Fall out Competition!

A prize of a handsome selection of Russian space achievement commemoration stamps is offered to that reader who, within a clear week prior to final decay, sends by mail, radio, telephone or packet radio that which calculates or guesses the nearest UTC time and date when SALYUT-7 returns to Earth. Up to only three entries each per reader, sent to G3IOR QTH as given here, via the AMSAT Nets, or via packet to G3IOR @ GB7VLS.

A useful formula for calculating the decay epoch is: - DE = ([16.66666666 - MM] / 10 x Decay) + RE where DE = Decay Epoch, MM = Mean Motion, RE = Reference Epoch.

RM-1 Launch

Leo Labutin, UA3CR, reports a further delay in the RM-1 launch. It is now expected to go aloft on 29 January 1991 with a pre and post launch on the air launch net on SSB and packet radio to give details and take incoming telemetry. Signals are expected from orbit as soon as it is powered up, on either 145.822 or 145.948 MHz, as it defaults to CW telemetry on activation. The telemetry (TLM) from beyond the UA command station's horizon is needed by the command team, and may be fed back by the nets or by packet radio.

G4CUO is greatly looking forward to performing some cross satellite QSO's by uplinking to RM-1 on 70cm and using RS-10 as a 2m to 10m 'IF', so hopes it will be on Mode 'B' frequently.

MIR

Unlike the latest American SHUTTLE SAREX missions, MIR is in a 340km high 96 minute period 51.6 degree inclination orbit, so in range of virtually the entirety of the populated world, albeit a non sun synchronous orbit.

Radio Amateurs of the Austrian OeVSV national society and the USSR RSF are currently phasing together by building the 'AREM' project, this name being an acronym for 'Amateur Radio Experiments on MIR'. The first package is scheduled for taking up and installation to MIR either by PROGRESS supply or by SOYUZ when two Soviet cosmonauts accompanied by a Japanese journalist visit the space station in January or February 1991. This AREM system augments the current voice MIR operations on 145 MHz FM with an automatic beacon transmitter which will broadcast information alternatively in AX.25 1200 bauds standard packet radio and synthesized voice transmissions.

The TNC will use standard 1200 bps FM AFSK with the usual AX.25, so that all earthbound Amateurs mode will be able to receive the transmissions and transmit back with their normal packet radio station equipment. For further information about the AREM project, you are invited to write to Wolf Hoeller, OE7FTJ, Amraserstrasse 19, A-6020 Innsbruck, Austria, enclosing an SAE and IRC's.

Yet a further improvement will be brought about by the installation of an external two metre antenna on MIR and sending up a 25 Watt transceiver for the use of the new crew, both of whom are licensed, one of whom may well be Alex, U5MIR again.

The voice synthesizer will use delta modulation, and messages of greetings and general information will be transmitted in the English, Russian and German languages, with data content alternating with the voice transmissions. The cosmonauts may at any time tasks permit, switch off the beacon and use the microphone for the odd rest time QSO, mainly 0430 to 0545 and from 1500 to 1730 UTC weekdays, and at any time between 0430 and 1800 at the week-ends.

The next stage, presently planned for November 1991, is for the addition of an uplink using simple BBS software, to permit two way space/Earth 145 MHz communications when the first Austrian cosmonaut joins the spacecraft crew with two other Soviet cosmonauts for such operations for a week. A lap top computer will be connected to both the TNC, modulator and voice synthesizer, which in turn will feed the current on board 145 MHz transceiver.

This new facility will be ideal for satellite beginners and for experimenters of all age groups. In particular the very large MIR station is a very big visual target. Up to one hour after local sunset and before dawn MIR at 340 kms altitude can be brightly sunlit and makes a superb naked eye object as it glides silently across the sky from west to east. Numerous combined visual and radio experiments are possible in these circumstances when you can actually see Mir go into Earth eclipse whilst in transit. ■

SAREX Hardware Development

By Lou McFadden, W5DID

Reprinted from the Proceedings *of the AMSAT Symposium.*

The SAREX (Shuttle Amateur Radio EXperiment) is the culmination of several years of development of Amateur Radio equipment for use in the NASA manned space program. The first proposal for amateur gear aboard a manned spacecraft was made by Harry Helfrich (W3ZM) at Goddard. The idea was to fly a 10M radio aboard Skylab for use by Owen Garriott (W5LFL). The proposal was favorably received by NASA management but couldn't be installed since it required an outside antenna, and it was too late in the buildup flow of Skylab. When the opportunity came up for Owen to fly again on the Shuttle Spacelab mission STS-9, an all out effort was made to provide the equipment needed for him to take aboard.

The work needed to make the SAREX possible is provided almost entirely by volunteers. They range from retired interested hams, to employees of NASA, NASA contractors, employees of Motorola and other electronic industry companies, ARRL and AMSAT. They have contributed many hundreds of personal hours to this effort with only their personal satisfaction as reward. Without the support of these many volunteers there simply would be no SAREX.

Most people have no concept of the requirements which must be satisfied in order to get a payload onboard the Shuttle. In general, the attitude of the NASA establishment is, " Prove you are safe and ready to fly and that you have completed all your paper work, then and only then can you get your equipment onboard". A very significant problem is determining what really is required. The documents which define that would take up an entire bookcase and then some, (needless to say it isn't for the faint of heart). There are constant new requirements cropping up. When the payload is not one of the Scientific payloads or a paying customer, the hurdles seem just that much higher. There are those that think of it as "a grown man's toy" which is taking up the space and weight which should be allocated to "real payloads". Then there are those who have the vision to see the benefit to NASA, the public and to the Amateur Radio community.

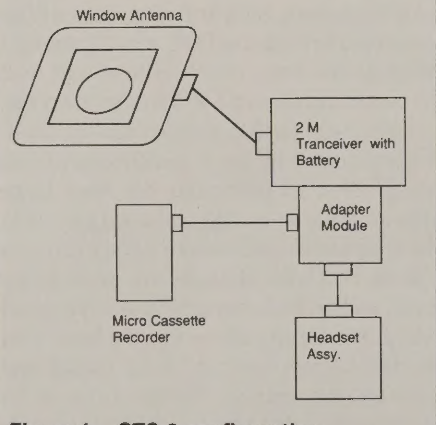

Figure 1— STS-9 configuration.

We have found that there are a great many people associated with NASA who are not hams but are sons, daughters, mothers, fathers, or friends of hams. There are many who want to be hams but don't ever get around to getting a license. These are the silent supporters that also make the SAREX project possible. Fortunately there are more of the friends of SAREX than those against it.

There are many documents required to be submitted to NASA in order to get approval for a payload to fly on the Shuttle. The most important of these is the PIP or Payload Implementation Plan.

This is the agreement between NASA and the payload provider. This document lists all the hardware, its weights, the experiment requirements and the flight needs and who is going to provide what equipment and perform which tasks. Another very important document is the Safety and Hazard analysis. This document lists all the hazards that are identified and how these hazards are controlled. It is not sufficient to say "well, that won't happen". NASA assumes it will happen and then wants to know how we intend to control the hazard. A good example of the kinds of hazards we had to deal with was " what if the SAREX radio upsets the Shuttle flight computers". This is a real hazard which we had to deal with. We dealt with it through analyzing the RF field strength and actual tests at KSC in the bird which proved that it wouldn't happen. Most of the work is very necessary considering the consequences of a catastrophic failure.

There were several other documents which had to be completed and approved by NASA before we could get the SAREX onboard. They are too numerous to list them all here.

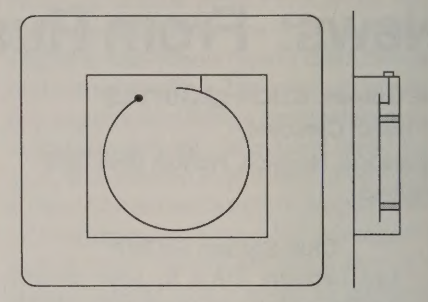

Figure 2 — Direct discontinuous ring radiator.

The equipment we assembled for Owen's flight was the simplest we could put together (Figure 1).

There were constraints on the SAREX (Called AMRAD on this flight).

Since it was the first flight on the Shuttle we decided to keep interfaces with the orbiter at a minimum. The intent was to minimize our chances for NASA to say no. The less complicated, the better chance we had and the fewer reasons they could find to remove AMRAD from the flight. This equipment consisted of a Motorola MX360 Handie Talkie and its batteries, an Adapter module to adapt the Shuttle crew headset to the HT, and an antenna designed to fit in the aft flight deck overhead window.

The HT output was adjusted so that the six Watt transmitter finals were limited to 2.5 Watts. This was necessary due to the lack of thermal convection cooling in the zero gravity flight environment.

The headset Adapter module was designed to take the low level microphone output (.5 mv) and amplify it to the level required by the Motorola HT. The Adapter module also provided the push to talk button and a mixed signal output with both sides of the conversation for the microcassette recorder. This allowed recording of this historic occasion on a cassette tape recorder.

The antenna chosen for the window was a DDRR or Direct Discontinuous Ring Radiator. This antenna system is analyzed by Dome in the July 72 issue of *QST* (p27-36). The ring is located in a box shaped cavity which is mounted on a flat plate designed to fit in the overhead window. The open side of the cavity faces the window (Figure 2). This antenna had the advantage of radiating out the window and at the same time providing a method of reducing the amount of RF radiating back into the cabin. The disadvantages were that it was extremely difficult to tune and it totally blocked the window.

The flight of STS-51F on which Tony

England was the operator presented new challenges. We were asked to provide something new and spectacular.

Specifically we were asked to provide a way to send pictures to the hams on the ground. The proposal included a SSTV (Slow Scan TV) system along with the voice capability. Another significant change was in the way of operating. There were more scheduled contacts, in particular those with schools and the families of the crew.

It was immediately recognized that in order to meet this requirement to send pictures to the ground, the "no electrical interfaces to the orbiter" rule would have to be abandoned. The power requirements were simply too much to allow dependence on batteries.

The initial configuration (Figure 3) also included a 10 Meter transmitter which would have required two additional batteries. The long term storage prior to flight also presents a significant shelf life problem for the batteries.

During our negotiations with the Shuttle program office prior to Tony's flight we went through several configurations. We even had a preliminary design of a 10 Meter antenna for the payload bay and a cable routing designed. An existing coaxial bulkhead feedthru was found behind the astronauts bathroom. All we needed was permission and funding for Rockwell to install the antenna and cable.

This idea was summarily disapproved. In fact, the request for the 10 M antenna and cable resulted in a disapproval letter being sent to NASA HQ which essentially tossed SAREX off the flight. After recouping from the shock of being thrown off the flight, we decided to take our SAREX proposal back with the 10 M portion deleted. Since the only reason given for the disapproval was the 10 M penetration, the program office approved the SAREX for flight.

The configuration that was finally approved included a new scan converter module, the existing Motorola transceiver and adapter module, antenna, and a Panasonic Camera and TV/monitor (Figure 4).

The scan converter module included the necessary isolated power supplies for the scan converter board, the camera, monitor and the transceiver, and the circuits to connect the scan converter to the camera and TV monitor. There was also a requirement to be able to bring Shuttle video into the SAREX so that we could send slow scan TV pictures from the shuttle cameras to the hams on the ground. This requirement presented a significant problem since the shuttle video is 75 Ohm BALANCED video and the SAREX system was unbalanced video. The NASA Lewis Amateur Radio Club built a custom balanced to unbalanced buffer board to provide this function. This also required the blessing of the NASA TV engineers, who are very cautious. An interface verification test was conducted to satisfy their concerns.

The SSTV converter was donated by Robot Research. The SSTV system needed modifications in order to meet the flight requirements for this flight. Special software was added to the Robot which allowed it to transmit a sequence of SSTV images in formats which were not in the Robot format. This would make the signals more universal and allow reception by SSTV enthusiasts who do not possess Robot hardware. Software modifications were also needed to process the Shuttle frame sequential video into a composite color image. The Shuttle video sends video in a green, red, blue frame sequence. These frames are digitized and stored in the SSTV converter memory and sent out as a composite color video signal. **This was the first time the Shuttle crew had the capability to see their own video in color onboard.** John Stahler (WB6DCN) of Robot Research provided the necessary software changes and the scan converter boards to include in the SAREX hardware.

Panasonic was very generous in providing the necessary cameras and TV monitors for the flight. The only changes necessary to the Panasonic hardware were conformal coating of the printed circuit boards to prevent shorts from metal particles in zero G, and shielding of the camera to protect it from the RF field from the SAREX transmitter. We all know the results of Tony's flight. There were hundreds of SSTV pictures received by hams on the ground and the first TV pictures were sent up to Tony from W5RRR as STS-51F passed over Houston. What an exciting event that was!

There were also many voice contacts with enthusiastic hams throughout the world.

Ron Parise's flight of STS-35 started out as a proposal by the NASA Goddard Amateur Radio Club to fly a Radio Shack model 100 laptop computer and the TAPR TNC2 along with the Motorola HT.

The STS-35 flight was originally planned for spring 1986. Much has transpired since then. The accident of STS- 51 L has completely changed the rules for flying hardware on the Shuttle. One of the changes is that all hardware has to be completely requalified. The Shuttle program office now provides the microcomputer used for all experiments. The configuration proposed for STS-35 called for incorporating the packet hardware into the SAREX scan converter module. In the years since the hardware for Tony's flight was built, the state of the art for power supplies has progressed greatly. This allowed us to incorporate the packet subsystem and the power supplies and scan converter into the same housing that was originally used to package the STS-51F hardware. The new power supplies are much more efficient and provide less of a heat dissipation problem. They also provide more current capability and are much smaller. They are the Lambda MLWx series power supply modules. As

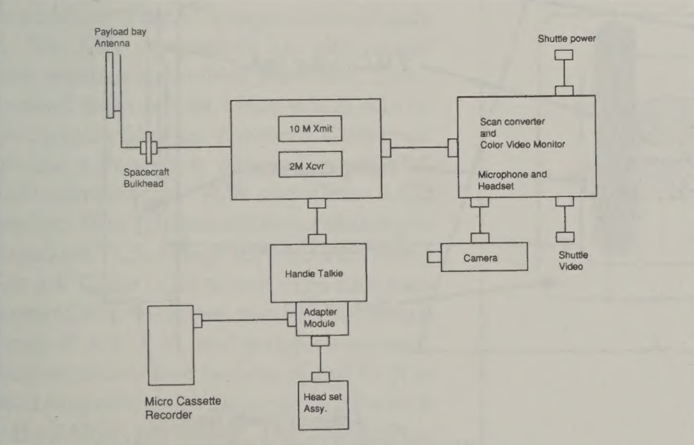

Figure 3 — Proposed STS-51 configuration.

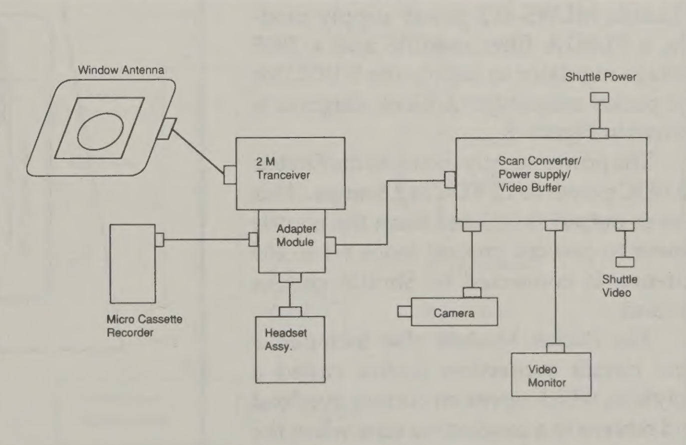

Figure 4 — Final STS-51 configuration.

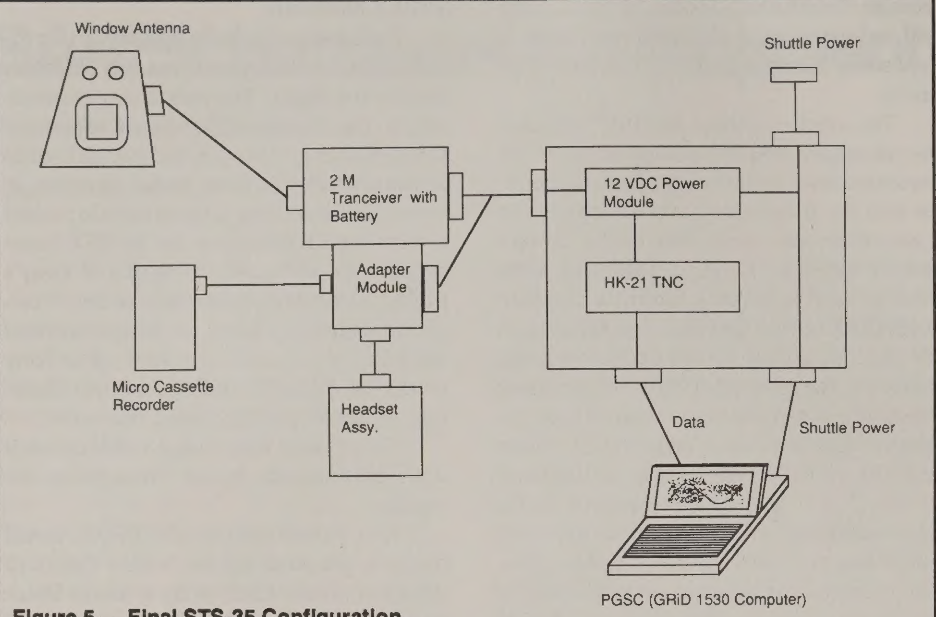

Figure 5 — Final STS-35 Configuration.

design was progressing on the new SAREX scan converter, we were notified by the Shuttle program office that there just wasn't enough room in the lockers for all the SAREX equipment. We were once again faced with the need to make a change or SAREX simply wouldn't be onboard. It was decided to add a new configuration to our growing inventory of SAREX hardware. Thus was born the SAREX Packet Module. The Packet Module is built into a 2.5" X 4.7" X 7.4" Bud CU-247 cast aluminum box. This new packaging and the sharing of the Shuttle provided laptop computer allowed all the unique SAREX equipment to fit into half of a stowage locker in the Shuttle mid-deck. Half a locker was all that was available. SAREX just barely made it again!

The new SAREX Packet Module includes a Heathkit HK-21 TNC which has been removed from the plastic case provided by Heathkit and mounted on the lid of the box. The power supply assembly is mounted in the bottom of the Packet Module housing. The power supply consists of a Lamda MLWS-912 power supply module, a FL461A filter module and a 7805 voltage regulator to supply the 5 VDC for the packet assembly. A block diagram is shown in Figure 5.

The power supply converts the Shuttle 28 VDC power to 12 VDC at 2.5 amps. This power output is isolated from the shuttle power to prevent ground loops when the antenna is connected to Shuttle chassis ground.

The Packet Module also included a new circuit protection device called a polyfuse, which opens on current overload and returns to a conductive state when the power is removed. This provides protection from current overload while not requiring the replacement of fuses.

The antenna for the STS 35 mission also provided the SAREX team with new challenges. The Astro mission is primarily an astronomy mission. Astronomical observations are conducted through the aft flight deck overhead windows. The SAREX antenna used previously on STS-9 and 51F only fits in the aft flight deck window. A new antenna was required if the time for SAREX operations was not to be severely limited. The design, fabrication, and qualification of a completely new antenna was a major undertaking. The SAREX team was also very short of funds and resources.

The Motorola Amateur Radio Club at Shaumberg, Ill. was solicited to design and build the antenna. The hams at Motorola were up to the task. Their antenna design (Figure 6) is an engineering marvel. This antenna is a variation of the annular slot antenna. The requirements for this antenna included: must not touch the glass, and must provide for transmitting on the 2 M band while at the same receiving on the 70cm band (to provide for a future ATV experiment). The prototype antenna had to be tested in the Shuttle prototype spacecraft Enterprise which is located at the Smithsonian Institute hangar at Dulles Airport in Washington, D.C.. There was no other place, except for the actual Shuttle, which had the necessary triple pane windows to simulate flight conditions. Most hams think glass has no effect on an antenna. How wrong! We found that the Shuttle windows detuned the antenna by 30 MHz! This put the team into a panic since the required delivery date for shipment to KSC was only 2 months away when this problem was discovered. The designer at Motorola, Jim Phillips, seemed confident that the problem could be solved. There were some of us at JSC that were more than a little nervous about it. The antenna had to be redesigned, fabricated and delivered to KSC in record time. What was worse, it had to be right! There would be no second chance. Fortunately, Jim is an expert of the first caliber (perhaps it was pressure from the ONLY Ham in the family, his wife Sharon, (KA9MTB) that gave him the incentive.) The antenna was delivered just in time. When we tested the flight hardware at KSC in the Shuttle Columbia, it worked perfectly! Jim had added

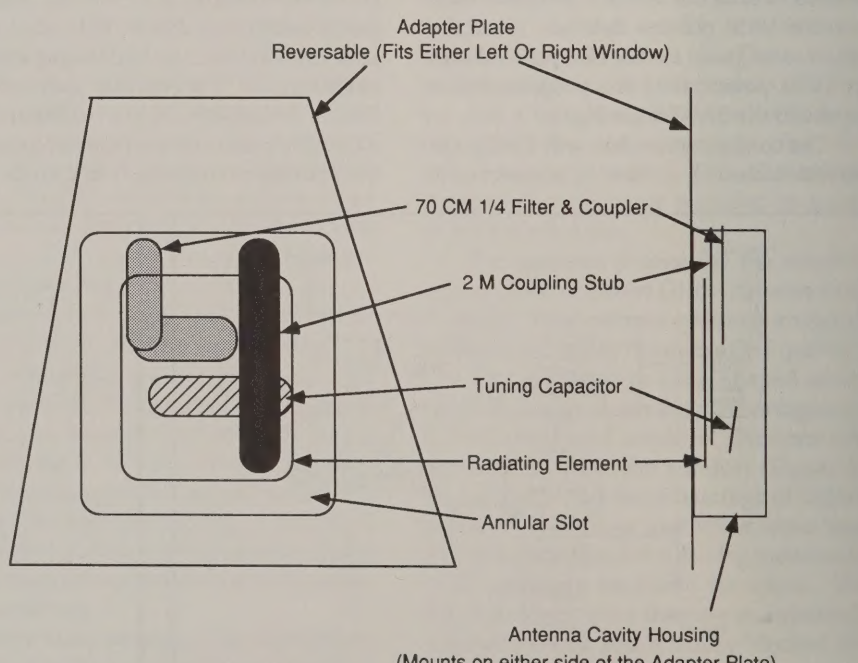

Figure 6 — SAREX II Antenna.

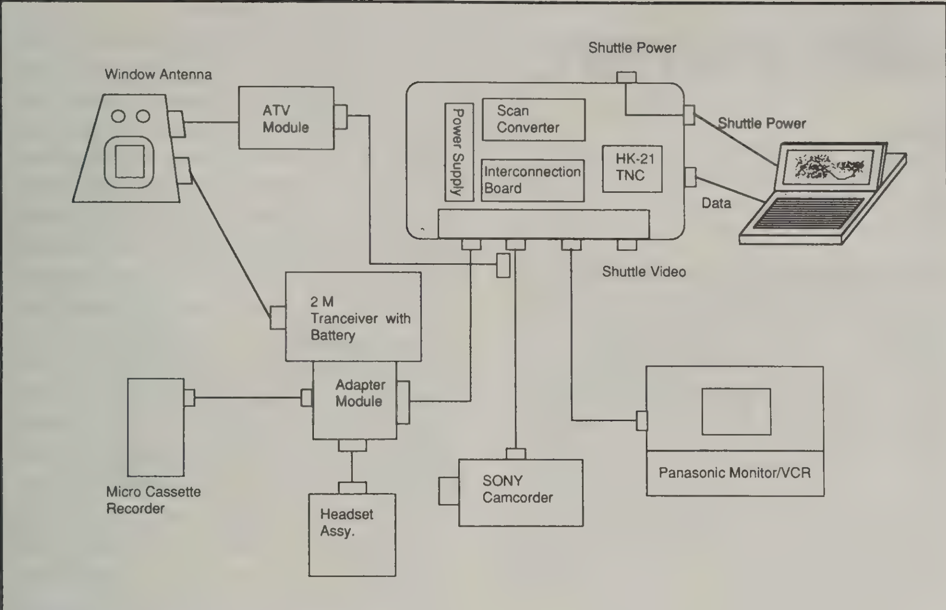

Figure 7 — Final STS-37 configuration.

a large tuning plate which had the capacity to shift the center frequency by 10 MHz. The Motorola team also added a reflected power indicator so that Ron could tune the antenna in flight. What a relief that successful test was to all who participated. Jim even got to go onboard the Columbia to test it himself.

We are now eagerly awaiting the flight of STS-35. This flight has been delayed several times and is now scheduled to fly no earlier than Dec. 1. This will certainly be the "most prepared for" Amateur Radio flight in history. We have been through the drill four times.

While we are waiting for STS-35 to fly, preparations are in full swing to assemble the hardware for STS-37. Ken Cameron (KB5AWP), Steve Nagel (N5RAW), Linda Godwin (N5RAX), and Jay Apt (N5QWL) are the hams onboard that flight. There will be more hams onboard STS-37 than in all other Shuttle flights combined! Their equipment will have all the capabilities originally planned for in Ron's flight, with the addition of an ATV experiment (Figure 7). The ATV experiment has also added some requirements which were new. There is a need to record the video which will be sent up to the Shuttle. The method planned will use a Panasonic donated model PV-M429 combination VCR and Color LCD monitor. This VCR has all the capabilities of a standard VCR, except for TV tuner, along with a 4" Color LCD screen. The unit uses standard VHS cassettes, measures approximately 4" X 8" X 9", and weighs 5 pounds. Another convenient feature of the VCR is that it runs off the 12 VDC already provided by the SAREX hardware. The Shuttle Provided Sony camcorder will be used as the video source for the SSTV operations. The same balanced to unbalanced buffer will be used to allow connection of the Shuttle frame sequential video to the SAREX.

The new SAREX scan converter module has been totally redesigned internally so that the packet feature could be added. The system consists of 5 major assemblies (Figure 8). The Packet sub assembly is very similar to the one used in the Packet Module. In fact it is "plug compatible " except for the LED cable. A Heathkit HK-21 is mounted on a cover plate which is then mounted on a box shaped sheet metal housing. The whole packet sub-assembly is designed to mount on the left heat sink that formerly held two of the power supplies on the STS-51 F scan converter. The mounting holes match those of the original power supplies.

These additions were made possible because of the advances that have been made in both power supply technology, and the progress in miniaturizing computer circuits, since 1984 when the first SAREX was designed.

The new SAREX power supply assembly consists of two 12 VDC 2.5 amp power supplies, one 5 VDC 3.0 amp supply, one +and - 12 VDC .6 amp power supply and an EMI filter assembly. All of these fit in a .75" X 3.3" X 6.6" assembly. This assembly is also designed to match existing mounting holes on the right heat sink from the STS-51 F scan converter.

The interconnection board, which provides all the interconnections between the various sub assemblies in the scan converter, was also redesigned. The new assembly provides the necessary switching to accommodate the addition of the packet sub assembly and provides a mounting platform for the balanced to unbalanced video buffer. All connections from the interconnection board are now made through connectors versus hard-wired on the earlier SAREX design. This will allow future modifications to be made more easily.

The Robot scan converter boards are virtually the same as they were on the earlier SAREX mission. The only changes required are in the CW Morse identification. It seemed appropriate to remove the Challenger WØORE ID. The new ID will be Atlantis KB5AWP.

The housing has been split into an upper and a lower housing to accommodate assembly. The old design was a nightmare to assemble and was very difficult to trouble shoot.

The front panel has also been exten-

(Continued on page 20)

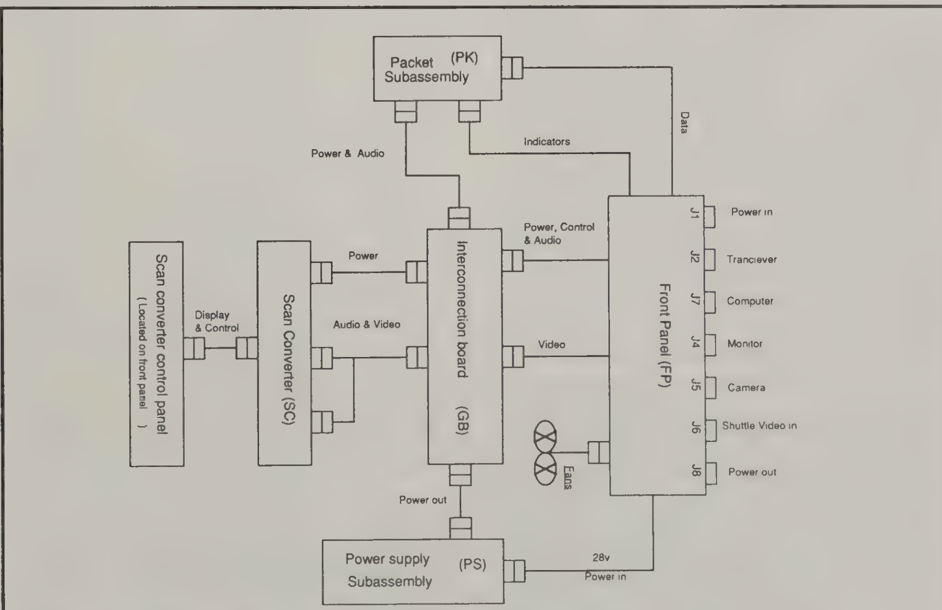

Figure 8 — SAREX scan converter internal subassemblies.

Decoding Telemetry from the Amateur Satellites

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By G. Gould Smith, WA4SXM
7605 Navarre Drive
Knoxville, TN 37919

The word TELEMETRY is derived from the Greek words 'tele' and 'meter', together they mean to measure from afar. Telemetry data from amateur satellites has been available since 1961. OSCAR I repetitively sent the CW message 'HI' at a speed related to the internal temperature of the spacecraft. The information gathered from this simple telemetry resulted in changes to the thermal coating and a lowering of the transmitter power for OSCAR II. The primary purpose of telemetry is to monitor, encode, transmit, and decode data concerning the vital systems of the satellite. The telemetry information gleaned from all the earlier satellites has contributed to a more reliable, longer lasting and fuller featured satellite.

Telemetry has two definitions. The most common usage is to refer to the 3 step process of: 1) converting analog data to digital data; 2) transmission of the digital data; and 3) conversion of the received signal into a displayable form. The other definition refers to the actual data itself. This dual definition often causes confusion when discussing telemetry. Telemetry generally measures four quantities: temperature, current, voltage and status. The first three can suitably describe the analog portion of the major systems. The fourth is needed to know the state of a device. Is it ON or OFF? The major components of the satellite offer an abundant amount of analog information available to be measured. It is the difficult job of the system designers to choose: 1) which values are to be monitored; 2) what mode of transmission is to be used; 3) how the data is to be encoded; 4) how much error detection to use; 5) how often to send the telemetry; 6) how much power to allocate to the transmission; 7) how fast to send the data; 8) how much memory can be allocated; and 9) how complex a ground station is needed. The major components of a satellite system are: 1) the power system; 2) the On Board Computer (OBC); 3) the Attitude control system; 4) the Transmitter; 5) the Receiver; 6) the Telemetry system; 7) and any on board experiments or transponders. Telemetry is used to monitor all the major systems. When any component is not functioning correctly it is important to quickly correct the problem. A satellite is an 'ecosystem', a system that must generate what it uses. The system must be kept in equilibrium or it will quickly fail. Determining the proper points to monitor, analyzing the telemetry, and using this analysis to keep the system in harmony will give the satellite its full controllable lifetime.

Basic Telemetry Description

A telemetry frame is the unit used to describe the collection of all the sampled points. The ideal frame is comprised of a group of attention characters, the header, all the data channels, the checksum and possibly a frame termination sequence. Most of the telemetry from amateur satellites contains all of these features. An individual data point is referred to as a channel. These data points are a measure of either the temperature at that point, the current passing through that point or the voltage present at that point. An analog to digital converter (ADC) is used to convert the temperature, current or voltage to a digital value that the On Board Computer (OBC) can store. Each ADC reads the analog value of a sensor a little differently, so it is necessary to calibrate each sensor / ADC connection. Figures 1 - 11 contain examples of many of the amateur satellite telemetry formats. First we will look at the major sections of a te-

Channel	Label	A	B	C	units
0	Rx E/F Audio(W)	+0.000	+0.0246	0.000	V(p-p)
1	Rx E/F Audio(N)	+0.000	+0.0246	0.000	V(p-p)
2	Mixer Bias V:	+0.000	+0.0102	0.000	Volts
3	Osc. Bias V:	+0.000	+0.0102	0.000	Volts
4	Rx A Audio (W):	+0.000	+0.0246	0.000	V(p-p)
5	Rx A Audio (N):	+0.000	+0.0246	0.000	V(p-p)
6	Rx A DISC:	+10.427	-0.09274	0.000	kHz
7	Rx A S meter:	+0.000	+1.000	0.000	Counts
8	Rx E/F DISC:	+9.6234	-0.09911	0.000	kHz
9	Rx E/F S meter:	+0.000	+1.000	0.000	Counts
A	+5 Volt Bus:	+0.000	+0.0305	0.000	Volts
B	+5V Rx Current:	+0.000	+0.000100	0.000	Amps
C	+2.5V VREF:	+0.000	+0.0108	0.000	Volts
D	8.5V BUS:	+0.000	+0.0391	0.000	Volts
E	IR Detector:	+0.000	+1.000	0.000	Counts
F	LO Monitor I:	+0.000	+0.000037	0.000	Amps
10	+10V Bus:	+0.000	+0.05075	0.000	Volts
11	GASFET Bias I:	+0.000	+0.000026	0.000	Amps
12	Ground REF:	+0.000	+0.0100	0.000	Volts
13	+Z Array V:	+0.000	+0.1023	0.000	Volts
14	Rx Temp:	+101.05	-0.6051	0.000	Deg. C
15	+X (RX) temp:	+101.05	-0.6051	0.000	Deg. C
16	Bat 1 V:	+1.7932	-0.0034084	0.000	Volts
17	Bat 2 V:	+1.7978	-0.0035316	0.000	Volts
18	Bat 3 V:	+1.8046	-0.0035723	0.000	Volts
19	Bat 4 V:	+1.7782	-0.0034590	0.000	Volts
1A	Bat 5 V:	+1.8410	-0.0038355	0.000	Volts
1B	Bat 6 V:	+1.8381	-0.0038450	0.000	Volts
1C	Bat 7 V:	+1.8568	-0.0037757	0.000	Volts
1D	Bat 8 V:	+1.7868	-0.0034068	0.000	Volts
1E	Array V:	+7.205	+0.07200	0.000	Volts
1F	+5V Bus:	+1.932	+0.0312	0.000	Volts
20	+8.5V Bus:	+5.265	+0.0173	0.000	Volts
21	+10V Bus:	+7.469	+0.021765	0.000	Volts
22	BCR Set Point:	-8.762	+1.1590	0.000	Counts
23	BCR Load Cur:	-0.0871	+0.00698	0.000	Amps
24	+8.5V Bus Cur:	-0.00920	+0.001899	0.000	Amps
25	+5V Bus Cur:	+0.00502	+0.00431	0.000	Amps
26	-X Array Cur:	-0.01075	+0.00215	0.000	Amps
27	+X Array Cur:	-0.01349	+0.00270	0.000	Amps
28	-Y Array Cur:	-0.01196	+0.00239	0.000	Amps
29	+Y Array Cur:	-0.01141	+0.00228	0.000	Amps
2A	-Z Array Cur:	-0.01653	+0.00245	0.000	Amps
2B	+Z Array Cur:	-0.01137	+0.00228	0.000	Amps
2C	Ext Power Cur:	-0.02000	+0.00250	0.000	Amps
2D	BCR Input Cur:	+0.06122	+0.00317	0.000	Amps
2E	BCR Output Cur:	-0.01724	+0.00345	0.000	Amps
2F	Bat 1 Temp:	+101.05	-0.6051	0.000	Deg. C
30	Bat 2 Temp:	+101.05	-0.6051	0.000	Deg. C
31	Baseplt Temp:	+101.05	-0.6051	0.000	Deg. C
32	FM TX#1 RF OUT:	+0.0256	-0.000884	+0.0000836	Watts
33	FM TX#2 RF OUT:	-0.0027	+0.001257	+0.0000730	Watts
34	PSK TX HPA Temp	+101.05	-0.6051	0.000	Deg. C
35	+Y Array Temp:	+101.05	-0.6051	0.000	Deg. C
36	RC PSK HPA Temp	+101.05	-0.6051	0.000	Deg. C
37	RC PSK BP Temp:	+101.05	-0.6051	0.000	Deg. C
38	+Z Array Temp:	+101.05	-0.6051	0.000	Deg. C
39	S band HPA Temp	+101.05	-0.6051	0.000	Deg. C
3A	S band TX Out:	+0.0451	+0.00403	0.000	Watts

Table 1 — DOVE telemetry decoding formulae.

Figure 1 — Sample RS-10 CW telemetry.

```
RS10    IS80 NR25 ID19 NG45 IW00 IK00 IO00
        AS35 AR23 AD38 MG31 AU00 AW46 AO89  RS10
```

lemetry frame, then discuss the decoding of each of the formats of amateur satellite telemetry.

Synchronizing Characters

Synchronizing characters are a sequence of characters to signal the beginning of a new frame. When a receiving station begins to acquire satellite telemetry it has no way of knowing where in the data stream it is. Odds are it is in the middle of a frame. The synchronizing characters tell the receiving system to start anew, to clear its buffer and begin a new frame sequence. AO-13 in PSK mode uses the ASCII sequence 39h, 15h, EDh, 30h, and in RTTY mode the traditional RYRYRYRYRY's. Many satellites use the 'HI HI' sequence in CW and ASCII mode.

Header Line

The header line follows the synchronizing characters. It normally identifies the satellite and contains some type of date/time group. The time that the data was sampled by the microprocessor is as important as the data itself. When analyzing the data it is necessary to know or be able to find out things like: whether the sun was shining on the satellite or not; what mode the satellite was in; or where the satellite was in its orbit. UTC is used for both the time and the date for all the amateur satellites. The DOVE time packet identifies the spacecraft, tells how long the current software has been running and gives the current UTC date and time. The AO-13 header line gives the same information, but adds a block or frame type. Often the date or both the date and time is coded to save memory space. It requires less power to transmit shorter data sequences. The decoding of the encrypted date/time groups for each satellite is covered in the format descriptions of the individual satellites.

Channel Data

This is the main objective for the telemetry transmission. In about half of the amateur satellite telemetry data fields the channel number is attached to the data. This is helpful in locating specific data and as a check. It does almost double the size of the telemetry data field, thus using quite a bit of power to transmit the extra characters. The actual data is transmitted as either a decimal, hexadecimal, octal or binary value. Different number bases are used by all of the amateur satellites. Often one satellite will send data in a variety of different number bases in a single frame. These are consistent and documented, so as long as you have the correct documentation, decoding should be a trivial exercise. As mentioned in the introduction to this section, each channel has a different calibration equation. These calibration equations are initially determined on the ground for each channel prior to launch. So when the data for each channel is received it must be normalized by its own calibration equation to give the true value of the channel measured. In addition to the analog data, status data is sent in the telemetry channels. Status is a binary function (ON or OFF), so the status points are usually transmitted as hexadecimal or octal values. These are then broken down by bit position. The state of each status function is then assigned by the 1 or 0 value in that bit position. Example #2 goes through the process of decoding status data.

Checksum

A checksum is used to validate the data and can be attached to each channel or encompass the entire frame. The data is useless unless it is valid. An even worse situation exists if erroneous data is considered valid and incorrect decisions are made because of this error. Some level of error checking is necessary, the difficult decision is how much to use. There are a number of different methods to assure the validity of the data. Unfortunately the better the error checking scheme the more characters the error checking requires. This can get to the point where there are more bits used in the error check than in the data it is validating. Obviously there has to be some middle ground that gives a reasonable level of integrity without using a large number of characters. Basically the checksum is some type of sum or XOR of the data and a comparison of the result with a known value. The checksum either passes and the data is valid, or fails and the data is invalid. Telemetry sent in AX.25 protocol have the checksum as part of the packet. Often there is a terminating sequence to signal the end of the telemetry frame. The Microsats use the WASH packet for this purpose.

Telemetry Decoding

The following descriptions for the decoding of amateur satellite telemetry begins with the telemetry format that requires the simplest receiving station setup and proceeds to the most complex setup. The simple to complex station determination is based upon both the equipment needed and the skills necessary to operate the equipment. Currently there are 8 distinct telemetry receiving station systems necessary to get data from all the active satellites. Many of the components are usable in more than one of the different systems. I have prepared a *Handbook of Amateur Satellite Telemetry* that contains: a thorough description of the telemetry from all of the active amateur satellites; calibration equations for each satellite; actual data decoded from each of the satellites; output examples from available telemetry decoding software; construction hints for most of the amateur satellite telemetry decoding units; large amateur satellite telemetry glossary and extensive amateur satellite telemetry bibliography. The handbook is available from the author. Table 2 lists the station equipment necessary to receive telemetry from each of the amateur satellites. Table 3 lists the telemetry beacon frequencies and telemetry transmission modes for all of the active amateur satellites. The eight current amateur satellite telemetry formats are:

1) Digitized speech: UO-11, DO-17
2) CW: RS-10/11, AO-13, FO-20, LO-19
3) RTTY: AO-13
4) 1200 bps AFSK packet: DO-17
5) 1200 bps AFSK ASCII: UO-11
6) 400 bps PSK ASCII: AO-13
7) 1200 bps PSK 8 bit packet: AO-16, WO-18, LO-19, FO-20
8) 9600 bps AFSK ASCII: UO-14

1. Digitized Speech Telemetry

Digitized speech telemetry has the simplest requirements for both equipment and operator skill of all amateur satellite telemetry. It also is the least efficient, has the least resolution and is the most prone to error. It is transmitted as an educational tool and to interest people in satellite activities. Data values from each channel are already calibrated when spoken, so writing down the data for each channel is all that is required. Digitized speech offers a fun, simple way to pursue an interest or to interest others in satellite operation. UO-11 does not transmit this form of telemetry very often.

2. CW telemetry

Reception equipment requirements for CW telemetry are minimal, but require more operator skill to receive the telemetry than the digitized speech telemetry. The data resolution is not as high as the other telemetry forms and no error checking is used. Most of the CW telemetry transmissions don't transmit the date/time group or label each channel. It is up to the operator to add

Table 2 — Compiled 8/90.

Amateur Satellite Telemetry Receiving/Decoding Equipment

1. Digitized Speech	
UO11, DO17	2M FM receiver and antenna
2. CW	
RS-10/11	HF/2M SSB receiver, stationary antenna, preamp helpful
LO19 **	435 MHz SSB receiver, stationary antenna, preamp helpful
FO20	435 MHz SSB receiver, stationary antenna, preamp helpful
AO13	2M SSB receiver, pointable antenna, preamp helpful
3. RTTY	
AO13	2M/435 MHz SSB receiver, pointable antenna, preamp, RTTY decoding unit, terminal/computer, RTTY data sent at 50 baud, 170 Hz shift, UnShift On Space OFF, USB on 70cm and LSB on 2m, software for IBM: AO13 RTTY decoding software for the IBM is available from Project OSCAR
4. 1200 bps AFSK Packet	
DO17	2M FM receiver, pointable antenna, preamp, standard TNC, terminal/computer, terminal setting: however the TNC is set - default 1200, 7, E, 1 software for IBM: TLMDC.EXE or NK6K decoding software from BBS or AMSAT-NA
5. 1200 bps AFSK ASCII	
UO11	2M FM receiver, pointable antenna, preamp, Bell type 202A modem, G3RUH demodulator, or modified PK-232, terminal/computer, terminal setting: 1200, 7, E, 1, software for IBM: by N5AHD from AMSAT-NA or G1WTW from AMSAT-UK
6. 400 bps PSK Packet	
AO13	2M/435 MHz SSB receiver, pointable antenna, preamp, 400 baud PSK demodulator to TNC, computer/terminal, terminal setting for G3RUH demodulator: 1200, N, 8, 1 software for IBM: by W9FMW AO13 telemetry decoding software from AMSAT-NA or P3C.EXE from AMSAT-UK or Project OSCAR
7. 1200 bps PSK Packet	
FO20	435 MHz SSB receiver, pointable antenna, preamp, 1200 baud PSK demodulator to TNC, computer/terminal, terminal setting - however the TNC is configured, software: none known
AO16,LO19	437 MHz SSB receiver, pointable antenna, preamp, 1200 baud PSK demodulator to TNC , computer/terminal, terminal setting - must use 8 data bits, software for IBM: TLMDC.EXE from BBS or AMSAT-NA
WO18	437 MHz SSB receiver, pointable antenna, preamp, 1200 baud PSK demodulator to TNC , computer/terminal, terminal setting - must use 8 data bits, software for IBM: TLMDC.EXE from BBS or AMSAT-NA, Weberware for picture reconstruction from AMSAT-NA
8. 9600 bps AFSK ASCII	
UO14	437 MHz FM receiver, pointable antenna, preamp, 9600 baud demodulator connected to receiver IF, computer/terminal software for IBM:

the date/time group to any CW telemetry received. Data values for each channel must be calibrated using a specific calibration equation. Each satellite has its own set of calibrations equations for each channel. An example of how to use the calibration equations is found following section 4 in Example #1. The CW calibration equations and complete decoding of the CW data are available in the *Handbook of Amateur Satellite Telemetry.* CW telemetry on the later satellites is transmitted more in deference to tradition than as an efficient method of satellite monitoring. The RS-10/11 telemetry beacon is most often found on one of the mode A beacon frequencies. Station equipment requires no more than a standard HF station for Mode A. The beacon for all modes is also used as the ROBOT CQ beacon and any QSO's interrupt the telemetry. The CW speed of 20 wpm and the fact that most ham receivers are not as sensitive at 29 MHz makes the RS-10/11 data a little more difficult to copy. Many stations use an inexpensive 10 M preamp to aid in data reception. RS-10/11 sends data for 16 analog values and 16 status points. Figure 1 has a sample of RS-10/11 CW telemetry.

FO-20 CW telemetry is also sent at 20 wpm, but there is less noise on 435 MHz than on 29 MHz, so the signal is easier to receive. The equipment needed for reception is slightly more than the standard UHF station. I have and still use inexpensive receive converters to capture data with a great deal of success. FO-20 CW telemetry is sent one frame/minute while the satellite is in Mode JA. The data consists of 12 analog items and 38 status items. Notice that FO-20 data does not contain either a satellite identification header or date/time group. The operator must record this data himself. Figure 2 has sample FO-20 telemetry data.

AO-13 CW telemetry is only transmitted during Mode B and at only 10 wpm. The equipment necessary to receive the telemetry is the most complex of all the CW telemetry receive stations. AO-13 tends to send more information bulletins/schedules than CW telemetry. LO-19 sent CW telemetry for the first few months after launch. The data values were sent in compressed Morse. This mode may or may not be reactivated.

Figure 2 — Sample FO-20 CW telemetry June 6, 1990.

HI HI	155 148 168 168
	285 284 242 262
	348 350 350 350
	407 437 410 437
	520 536 500 500

3. RTTY Telemetry

AO-13 currently is the only amateur satellite that routinely transmits telemetry in RTTY. The transmissions occur during both Mode B and Mode J operation. These transmissions begin at 15 and 45 minutes past the hour for both Modes B and J. During Mode J operation, RTTY replaces the CW transmissions on the hour and half hour. These transmissions last for approximately 5 minutes, then the telemetry returns to PSK mode. Both telemetry and bulletins are transmitted, usually alternating. RTTY requires a more complex receiving station than digitized voice or CW, but provides more data in the same amount of time. The AO-13 telemetry is sent at 50 baud, standard 170 Hz shift, UnShift ON Space OFF or disabled, USB on 70cm and LSB on 2m. The AO-13 RTTY telemetry contains the first 60 of 128 available channels plus the Safety Information Word, transponder status byte and the command count. Unless the satellite is very close to the Earth a fairly sophisticated station is necessary. Publications that contain the calibration equations for all 128 channels are available from AMSAT-NA or AMSAT-UK. Project OSCAR has IBM software available that takes an ASCII file of the RTTY data and decodes it. Figure 3 has sample AO-13 RTTY telemetry. This telemetry is very similar to the AO-13 PSK telemetry and is decoded the same way (See section 6). The Z block designation says this is RTTY data. Notice that a message immediately follows the telemetry.

```
RYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRY
RYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRY
RYRYRYRYRYRYRYRYRYRYRYRYRYRYRYRY
Z  HI. THIS IS AMSAT OSCAR 13
      20.45.29  4568
.0026   .0000    .0171

64  14  0   1   13  229 0

235 7   155 135 193 7   150 82  200 7
137 7   116 7   151 31  7   7   156 7
12  7   138 62  18  7   141 69  118 7

138 7   169 136 139 57  134 141 141 7
137 147 140 18  227 133 127 7   179 137
134 7   76  140 139,141 14  130 130 207
HI THIS IS AMSAT OSCAR 13 04JUL90
AO13 TRANSPONDER SCHEDULE
MODE B  MA 003 TO 165
MODE JL MA 165 TO 190
MODE LS MA 190 TO 195
MODE S  MA 195 TO 200
MODE BS MA 200 TO 205
MODE B  MA 205 TO 240
OFF     MA 240 TO 003
OMNIS   MA 240 TO 060
```

Figure 3 — Sample AO-13 RTTY telemetry from July 4, 1990.

4. 1200 BPS AFSK Packet Telemetry

DOVE (Digital Orbiting Voice Encoder) or DO-17 is once again transmitting AX.25 telemetry data on 145.825 MHz FM. The data can be collected with a standard 2M FM receiver and 1200 bps AFSK packet TNC. A good terminal program can be used to store the received data to disk for later analysis. Dove uses 59 (3A hexadecimal) telemetry channels to report the current condition of the satellite. Each telemetry frame/block begins with the DOVE telemetry frame collection time line. This line contains the satellite identifier, uptime and date/time group. The uptime is the length of time the current software has been running. The date/time group is the current UTC time. The 59 data channels follow. Note that the channel numbers and the channel data are hexadecimal numbers (hex or base 16). This is because the onboard microprocessor operates in hexadecimal and it is more efficient to transmit than base 10.

Dove breaks the 59 telemetry channels up into 2 segments. The first segment is composed of channels 00 - 20H and the second segment is 21H - 3AH. These are followed by the status channel data and the termination line labeled WASH. The wash label was coined because of its function, to clean out the buffer. The termination line lists both the current address and the number of error detections and corrections performed. These transmissions occur every 10 to 20 seconds, so on a good pass you could receive about 90 sets of data. I have chosen the DOVE telemetry on which to do extensive decoding because it offers: 1) a good, generalized telemetry format; 2) the data is easily captured; and 3) it provides quite a bit of interesting data. Figure 4 contains a current frame of DOVE telemetry. Example #1 decodes the data in Figure 4 using the calibration equations in Table 1.

Once the data has been collected the analysis can begin. Table 1. lists the calibration equations necessary to decode the DOVE telemetry. The DOVE-1>TLM: address identifies this as telemetry. The line contains first the channel followed by the data value for that channel. Note that both the hex channel number and the hex data are separated by a colon. Channel 00H has a data value of 59H, which we need to convert to decimal for substitution into the calibration equation to compute the true value of the channel.

Using Table 1 the general formula used to convert DOVE telemetry is:

$$Y = Cx^{2} + Bx + A \quad \text{or} \quad Y = A + X(B + (X^{*}C)),$$

where A, B, & C are the calibration constants for each channel and X is the decimal data value received for that particular channel. This is a slightly different arrangement of the calibration constants than have previously been published. I changed them because a number of people I gave the equations to substituted the constants incorrectly.

This example uses the DO-17 telemetry from Figure 4. Look through the list of

Example #1

```
channel 1Bh has a value of 7Fh (127 base 10),  solving using the general Dove
formula:
Y = 1.8381 + 127( -0.003845 + (127*0)) -> 1.8381 + ( -0.488315) -> 1.35 V
On Mon Jul 23 1990 03:52:18 UTC, the voltage of DOVE Battery #6 was 1.35 volts.

DOVE channel 35h has data value of AAh.
AAh -> Ah = 10 decimal, so 10 x 16 = 160    +  (Ah or 10) = 170 data value

channel  description          A            B           C             unit
35       +Y Array Temp   +101.05      -0.6051      0.000           Deg. C

Y = A + X( B + (X*C))
Y = 101.05 + 170( -.6051 + (170*0))
Y = 101.05 + 170( -.06051 + 0)
Y = 101.05 + ( -102.867 )
Y = -1.10 degrees C
The temperature of the +Y side panel was  -1.10 degrees C.

         ==========================================

Channel      Calibration equations

6        10.427 + 111( -0.09274 + (X * 0)) --> 0.1328 kHz receiver A DISC
7        0.0 + 73( 1.0 + X(0)) --> 73 counts on receiver A S meter
A        0.0 + 162(0.0305 + X(0)) --> +4.941 V on the +5 V Bus
B        0.0 + 220(0.000100 + X(0)) --> .022 A or 22 mA +5V receiver
13       0.0 + 1(0.1023 + X(0)) --> +0.1023 V on +Z array

16       1.7932 + 155( -0.0034084 + (X * 0)) --> 1.264 V on Battery #1
17       1.7978 + 154( -0.0035316 + (X * 0)) --> 1.253 V on Battery #2
18       1.8046 + 156( -0.0035723 + (X * 0)) --> 1.247 V on Battery #3
19       1.7782 + 155( -0.0034590 + (X * 0)) --> 1.242 V on Battery #4
1A       1.8410 + 152( -0.0038355 + (X * 0)) --> 1.258 V on Battery #5
1B       1.8381 + 148( -0.0038450 + (X * 0)) --> 1.269 V on Battery #6
1C       1.8568 + 160( -0.0037757 + (X * 0)) --> 1.252 V on Battery #7
1D       1.7868 + 156( -0.0034068 + (X * 0)) --> 1.255 V on Battery #8

26       -0.01075 + 0( +0.00215 + (X * 0)) --> -0.01075 mA from -X array
27       -0.01349 + 0( +0.00270 + (X * 0)) --> -0.01349 mA from +X array
28       -0.01196 + 0( +0.00239 + (X * 0)) --> -0.01196 mA from -Y array
29       -0.01141 + 0( +0.00228 + (X * 0)) --> -0.01141 mA from +Y array
2A       -0.01693 + 0( +0.00245 + (X * 0)) --> -0.01693 mA from -Z array
2B       -0.01137 + 0( +0.00228 + (X * 0)) --> -0.01137 mA from +Z array
no current from any of the solar panels, so the satellite is in eclipse

14       101.05 + 181( -0.6051 + (X * 0)) --> -8.473 Deg C receiver temperature
15       101.05 + 163( -0.6051 + (X * 0)) --> +2.418 Deg C (+X) receiver temperature
2F       101.05 + 164( -0.6051 + (X * 0)) --> -1.81  Deg C battery #1 temperature
34       101.05 + 202( -0.6051 + (X * 0)) --> -21.18 Deg C PSK TX HPA temperature
35       101.05 + 170( -0.6051 + (X * 0)) --> -1.81 Deg C +Y array temperature
38       101.05 + 191( -0.6051 + (X * 0)) --> -14.5 Deg C +Z array temperature
```

```
DOVE-1>TIME-1:PHT: uptime is 001/01:10:22.  Time is Mon Jul 23 03:52:18 1990


DOVE-1>TLM:00:59 01:58 02:88 03:30 04:56 05:56 06:6F 07:49 08:6C 09:6A 0A:A2
0B:DC 0C:E8 0D:D6 0E:00 0F:24 10:C8 11:88 12:00 13:01 14:B5 15:A3
16:9B 17:9A 18:9C 19:9B 1A:98 1B:94 1C:A0 1D:9C 1E:21 1F:5D 20:BC


DOVE-1>TLM:21:8E 22:78 23:1C 24:1C 25:35 26:00 27:00 28:00 29:00 2A:00 2B:00
2C:00 2D:30 2E:00 2F:A4 30:D2 31:A4 32:06 33:28 34:CA 35:AA 36:B1
37:B0 38:BF 39:85 3A:87


DOVE-1>STATUS: 80 00 00 85 B0 18 55 02 00 30 00 00 09 0B 3C 05 29 5A 03 04
DOVE-1>LSTAT:I P:0x3000 o:0 1:13081 f:13081, d:0

DOVE-1>WASH:wash addr:3640:0000, edac=0x3f
```

Figure 4 — Sample DOVE telemetry.

```
UOSAT-2             9008046141320

0051620l395E0223210357230405320503710602040705200804590904OD
```

Figure 6 — UO-11 telemetry.

labels in Table 1 and select a channel that looks interesting. Find the data for the selected channel in the telemetry frame (Figure 4.), convert the hexadecimal data value for the selected channel to decimal. Then substitute the value for X, and substitute the selected channel constants for A, B, & C in the general calibration equation. Finally solve the equation and append the descriptive label to complete the decoding of the selected channel.

The general formula used to convert DOVE telemetry is : Y = A + X(B + (X*C))

5. 1200 BPS AFSK ASCII Telemetry

UO-11 (UoSAT-2) is currently the grande dame of the active amateur satellites. It was designed by the UoSAT Spacecraft Engineering Research Unit at the University of Surrey, England. Launched on 1 March 1984, it is still alive, very well and sending quite a bit of very interesting telemetry. The more data I gather and the more I learn about the experiment aboard the satellite, the more impressed I am with this UoSAT-2. Since UO-11 is an educational/experimental amateur sat-ellite most of its function is to gather data and transmit the experimental data. UO-11 also has a DCE (Digital Communication Experiment, digital store and forward system) aboard that was sending packet data around the world before most 'hams' had even heard of the word packet. Also aboard is a CCD camera that has been taking pictures of the Earth, converting them to digital data and sending them back to Earth for over 6 years.

The Space Dust experiment logs the number and momentum of small particles hitting the spacecraft. Studies of the Earth's magnetic field are done by the Particle Detectors and Wave Correlator Experiments. All this data comes down via a simple modulation scheme of sending ASCII data by shifting between 1200 and 2400 Hz to convey the 1's and 0's. This ASCII data comes down at 1200 baud and can be copied by a Bell 202 modem, the bit sense will need to be reversed though. This is NOT the same 1200 baud modem you probably are using with your computer, you have a Bell 212 modem that uses a different modulation scheme. James Miller has published the schematic for a good demodulator in *Electronics* and *Wireless World* and *Ham Radio* magazines. AMSAT-UK also sells a printed circuit board for the builders among you. There are also

```
0479522522522522A2
048152152149852227
048925651643952158
049124251551845552
049952152152135356
    ...
0000000100200305B
000551642118152OCF
000D33351416252OD7
001513551451752115
001D43351851922307
    ...
0475522522522522A6
047D5225225225229E
048539751939252lBF
048D202515517521CA
0495371518519384EC
    ...
0000000100200305B
0003516177248522B$
000B455517134520E6
001315051444852OCD
001B351515518260B3
```

Figure 7 — partial UO-11 WOD data.

simple modifications to the AEA PK-232 that allow it to copy UO-11 telemetry. The data is sent at 1200 bps, 7 data bits, even parity.

As important, as the UO-11 demodulator, is a good receiving station. The ability to track the satellite from horizon to horizon and a signal with a good S/N ratio are necessary to get consistent telemetry. Any investments in a receiving station are the best ones you can make. The actual satellite telemetry contains 70 channels of data. These are sent in 7 lines of 10 channels each. 59 of these channels contain analog measurements, with the remaining 11 channels reporting 96 status points. Figure 6 is an actual UO-11 telemetry frame. The satellite identifier is obvious, but the date/time group may be a bit cryptic. It is in YYMMDDWHHMMSS format. (UTC year, month, day), day of the week (Sunday = 0), HHMMSS (UTC hours, minutes, seconds).

Example #2 — Selective decoding of UO-11 telemetry.

```
Channel 00 of UO-11 is the -Y solar array current.  The first 5 characters of
data line #1 make up the channel 0 data package.  00 is the channel number, 516
is the data, and 2 is the hex checksum. To calibrate the data, substitute the
data for N in the calibration equation for channel 0:

 I = 1.9(516 - N) --> 1.9 (516 - 516) -> 0 mA
tells us that solar panel -Y is in the dark.

Channel 28 is the temperature of the -Y panel.  Data line #2 contains the
information for channel 28 - 28474D.
The data value 474 is substituted into the equation: T = (480 - N) / 5 ->
       (480 - 474) / 5 -> 1.2 deg C for panel -Y.
This says that panel is cooling or warming, by looking at the previous and post
frame we can tell which.

The Digital Status Channels (60 - 67) contain 12 status items per channel.  The
data is 3 hex digits that are broken down into binary.  Channel 60 has data 83E
which equals
(MSB) 1000 0011 1110 (LSB) binary.  The status definitions for channel 60 are:

          Function                              0     1
(MSB) 145 MHz General Beacon power             OFF   ON
      435 MHz Engineering Beacon power         OFF   ON
      2401 MHz Engineering Beacon power        OFF   ON
      Telemetry channel mode select            Run   Dwell

      Telemetry channel dwell address load     OFF   ON
      Telemetry channel dwell address source   GND   Computer
      Primary Spacecraft Computer power        OFF   ON
      Primary Spacecraft Computer error count  bit 1

      Primary Spacecraft Computer error count  bit 2
      Primary Spacecraft Computer bootstrap    UART  PROM
      Primary Spacecraft Computer error count  bit 3
(LSB) Primary Spacecraft Computer bootstrap    A     B

Channel 60 tells us that the 145 General beacon is ON, the 435 and 2401 beacons
  are OFF.  Channel mode select is in RUN
Channel dwell address load is OFF
Channel dwell address source is Ground
Primary spacecraft power is ON
Computer error count is 111 or 7
Bootstrap is from PROM A
```

```
                       section 2                       section 3
                  0000 000 010 020 030 5B     0000 000 010 020 030 5B
                  0005 516 421 181 520 CF     0003 516 177 248 522 B$
                  000D 333 514 162 520 D7     000B 455 517 134 520 E6
                  0015 135 514 517 521 15     0013 150 514 448 520 CD
                  001D 433 518 519 223 07     001B 351 515 518 260 B3

     section 1                ...
0479 522 522 522 522 A2   0475 522 522 522 522 A6
0481 521 521 498 522 27   047D 522 522 522 522 9E
0489 256 516 439 521 58   0485 397 519 392 521 BF
0491 242 515 518 455 52   048D 202 515 517 521 CA
0499 521 521 521 353 56   0495 371 518 519 384 EC
```

Figure 8 — UO-11 WOD data rearranged.

```
* UOSAT-2 OBC STATUS INFORMATION *

DIARY OPERATING SYSTEM V3.1 SMH MLJM MSH

 Today's date is 17 /8 /90  (Friday)
 Time is 1 :34 :24 UTC
 Auto Mode is selected
 Spin Period is - 226
 Z Mag firings  = 0
 + SPIN firings = 31
 - SPIN firings = 22
 SEU count      = 705
 RAM WASH pointer at 170A
 WOD commenced 17 /8 /90 at 0 :0 :8
 with channels 0 ,10 ,20 ,30 ,
 Last cmnd was 109 to 0 , 0
 Attitude control initiated, mode 1
 Data collection in progress
 Digitalker active

**** UoSAT-OSCAR-11 BULLETIN - 218
```

Figure 9 — Portion of UO-11 bulletin.

So the data in Figure 6 was gathered Saturday 4 August 1990 at 14:13:20. Each channel's data is composed of 5 digits. The first two are the decimal channel number. Three decimal data values follow. The last character is the hex checksum for the channel, so the ground stations can validate the data for each channel. The data values are calibrated using the UO-11 calibration equations available from AMSAT-UK in a very informative publication named *UOSAT SPACECRAFT DATA BOOKLET* and in the *Handbook of Amateur Satellite Telemetry*. There are also a number of interesting bulletins sent as part of the regular schedule of telemetry from UO-11.

One of the biggest problems with telemetry reception is that you only get data for the limited time that the 'bird' is in view. The designers of UoSAT-2 attempted to solve this with their DSR experiment (Digital Store and Readout). This experiment stores telemetry data for selected channels for an entire orbit, or a CCD picture, or particle counter experiment data and outputs them in an error encoded format. Thus WOD (Whole Orbit Data) was developed to allow the receiving stations to know what happens to particular onboard devices during an entire orbit. The WOD is usually composed of 4 - 6 channels of data that are sent in a very clever manner. The complete data set is divided into 4 sections. Each section sends data 8 time units apart. If the data takes a noise hit or the signal fades a complete area of the whole orbit data is not lost. The other 3 sections will each have 2 of the remaining 6 time units of data that were hit. This allows the entire orbit profile to be constructed from just one section (1/4 of the data), albeit with a slight lost in resolution. The time unit for UoSAT-2 (UO-11) at 1200 baud is 4.84 seconds. Figure 7 shows an abbreviated example of WOD received from UO-11. This data records the solar cell current for the (-Y, +Y, -X, +X) sides of the satellite. The complete data set will be referenced later to demonstrate telemetry analysis. The complete set of data is formed by interleaving as much of the four sections as was captured. You will rarely be able to receive the entire WOD on one pass, but you may be able to get at least 2 partial and 1 complete sections. Figure 7 is such an example. The ... sequence symbolizes that data was omitted. The line that begins with '0000' is the channel identification frame. The first 4 digits are the hex number of time units into the sample, then each group of three defines the channel and the last 2 are the checksum. From Figure 8 you can see that this WOD is for channels 000, 010, 020, 030 and 5B checksum. Figure 8 takes the data from Figure 7 and rearranges it into its three sections. Spaces have been added between channels to aid in data identification. Notice that in section 1 the data is at time intervals 1 and 9; in section 2 at time intervals 5 and D; and section 3 at time intervals 3 and B. The uncopied section must have been at time intervals 7 and F. The WOD start and stop times are sent in the telemetry bulletins. Figure 9 has a portion of a UO-11 bulletin.

6. 400 BPS PSK ASCII Telemetry

This is the predominant form of telemetry on AO-13, 40 minutes out of each hour. The station complexity increases a great deal here because a specialized piece of equipment is needed and a good receiving station is mandatory. The operator skills required are the ability to track the satellite and tune in the signal. Again the investment in the station's receiving capability is one of the best you can make. A 400 bps PSK demodulator interfaced to a TNC is necessary for AO-13 PSK telemetry reception. These are available in kit form or as a working unit, both need to be interfaced to a TNC though the modem disconnect header. The telemetry from AO-13 is extensive and provides quite a bit of interesting data about the satellite. Bulletins and messages (between the control stations) alternate with the telemetry. Two good programs for the IBM are available to decode and log the telemetry. The P3C.EXE program from AMSAT-Australia is geared toward realtime decoding. The channel data is organized by categories and placed in boxes on the screen. This program is available from AMSAT-UK and Project OSCAR. The W9FMW AO-13 program is designed for post-processing and makes a very nice printout or ASCII file of the telemetry. This is available from AMSAT-NA.

AO-13 sends its telemetry in 512 byte labeled blocks/frames. These frames are labeled as K, L, M, N, Q, Y blocks. RTTY is sent in Z blocks. Text messages are sent in the K, L, M, and N blocks. The Q blocks contain 128 analog values in hexadecimal. Y blocks are the first 64 of the 128 channels. The fact that the data is sent as 8 bit hexadecimal makes it a little tricky to store with a terminal program. I had quite a bit of trouble with ProComm Plus until I discovered that the log to file function did not log all the ASCII control characters. The ASCII download function needed to be used instead. AMSAT-UK has an excellent publication on AO-13 by RWL Limebear, *AMSAT-UK OSCAR 13 OPERATIONS AND TECHNICAL HANDBOOK.* This publication has a great deal of detailed information on AO-13 and lists the telemetry calibration

```
Q  HI, THIS IS AMSAT OSCAR 13                        02:39:31  4581
#0026   #0020   #017A
64  9  0  1  17  230  0

 193   7 152   7 193   7 165 115 200   7 136   7 100   7 153  29
   7   7 138  54   9   7 136 136  16   7 139 151 116   7 137   7`
 147 134 136   7 220 149 134   7  75 149 134 165 227 132 127  55
 179 133 139  94 146 144 138   7  13 141 125   7 208 140 132   7
  64   9   0   1  17 230   0   0  10   3 105  84   5  40  65  32
  65   0 152   0 148   0  38  55   0 205   3   5   0   0  32   0
   0 250   0 100  14 210  65   6  14  33  39   2 229  17   1   0
   0   0   1   0   0   0   1   0   0   0   1   0  38   0  17   0
```

Figure 10 — Sample AO-13 PSK telemetry data Q block.

```
WEBER-1>TIME-1:PHT: Uptime is 089/09:25:25.  Time is Sat Aug 18 04:40:36 1990
                *
WEBER-1>STATUS:00000085B01888010093E7F507093C058E000000
WEBER-1>LSTAT:I P:0x1A9C o:0 l:193-4 f:1934
numerous photo frames sent here ...

              **
WEBER-1>TLM:007A01730271037E047C059006770786087B09370AA60BA70CD00DBE0E080F75
            10B411901206137014AD15A61689178318801985 1A7E1B891C801D8C1E271F60
            2094217A2278233F243B252C2600270028002900 2A002B002C002D302E002FA6
            30A631A73237336D34B035B036BA37AE38D539A63AA63BA13C9B3DFF3E493FD6
            40A641A542D6
                ***
WEBER-1>STATUS:00000085B01888010093E7F507093C058E000000

WEBER-1>CAST:


Current pic 5 is directly into sun.

Quite spectacular.  Will xmit it often

during the next few days.  Enjoy

73's WA3PSD

*(C5 C6 CC 26) character sequence sent between : and 0
**(E3 C6 CC 26) character sequence sent between : and 0
***(E3 C6 CC 26) character sequence sent between : and 0
```

Figure 11a — Microsat telemetry.

equations. Figure 10 is an AO-13 Q block that has all 128 channels of data. The 128 channel data in this Q block have been converted to decimal. The 7 normally means that no data is available, but it also is the ASCII terminal BELL character. So be prepared for a great deal of beeping. The unusual number in the date/time group is the date. Here it is encoded as the number of days since 1 JAN 1978 (1 JAN 1990 = 4382). So the AO-13 frame in Figure 10 was sent on day 199 of 1990 or 18 JUL 1990. Lines 2 and 3 are status items to quickly alert the command stations to a potential problem. There are no channel identification numbers, it is done strictly by position. There is an elaborate checksum (CRC, cyclic redundancy check) sent after the block to determine the validity of the entire frame.

7. 1200 BPS PSK Packet Telemetry

The telemetry form of choice for the Microsats and FO-20 is 1200 bps PSK packet. This form has evolved to be among the most efficient and complex to decode. The range of equipment needed and the skill of the operator are also among the most advanced. This challenging aspect of the hobby is what makes it interesting for many of us. The data is sent as 8 bit hex and ASCII frames interspersed between the packet BBS or CCD picture data download. The equipment needed to receive the Microsats and FO-20 is actually the same equipment needed for FO-12. See we don't always have to re-equip the station with each new satellite.

Decoding the Microsats N4HY has written a program to decode all the Microsat telemetry, TLMDC.EXE available on CompuServe's HAMNET, DRIG BBS or from AMSAT-NA. The calibrating equations are very similar to those of DOVE and have been published a number of places. The DOVE telemetry in Figure 11a, recognizable by the TLM address, is actually sent as a stream of digits with no spaces, carriage returns or linefeeds. I altered the format to make it easier to reference and fit on the page. Both the channel identification and data are one hexadecimal byte each. Channel 0 in Figure 11a has a data value of 7A. Convert this to decimal and substitute in the appropriate calibration equation. Examples of this process are found in Example #1. WO-18 has a number of interesting experiments aboard that send their data as telemetry. The CCD camera experiment sends pictures taken of the Earth from WO-18 in AX.25 packet frames. Each frame is numbered and reassembled into a picture by WEBERWARE V1.0 software at the receiving station. Other experiments sending telemetry include:

1) The impact sensor experiment that samples the impact counter and the current readings at 5 second intervals. Each impact will increase the count by about 16.

2) The horizon intercept sensor has 2 photocells with a field of view of 10 degrees each. The photocells are angled so that they cross about a foot in front of the spacecraft. They are used to determine when the spacecraft is pointed toward the Earth and not the sun. The Earth is the only object close enough to illuminate both sensors.

3) The flash D/A board experiment takes digital data from the onboard computer memory and produces an analog waveform. This waveform can modulate an FM signal, providing an experimental method of downloading a great deal of data quickly.

4) The magnetometer experiment notes changes in the Earth's magnetic field.

5) A light spectrometer to measure the spectral content of light entering through a slit in the (-Y) face. These experiments provide an excellent opportunity to investigate and learn something new.

```
8J1JBS>BEACON:JAS1b RA 90/05/07 03:49:58
427 453 669 678 729 836 847 829 001 660
617 000 498 497 521 516 519 522 654 000
644 644 644 619 999 646 879 485 026 010
010 111 100 000 111 100 101 110 010 000
```

Figure 11b — FO-20 telemetry data.

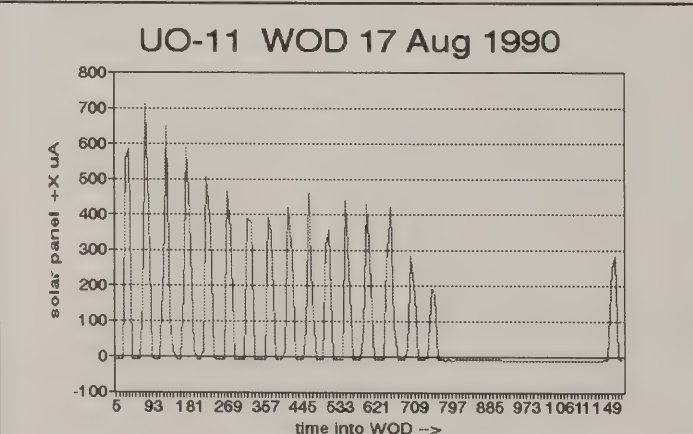

Figure 12

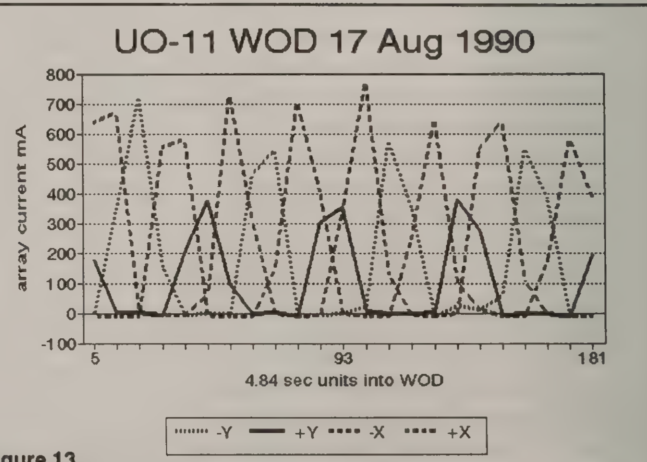

Figure 13

SATELLITE	FREQ MHz	Mode	Transmission type
RS-10	29.360	KA, K, A	CW @ 20 wpm
	29.403	KA, K, A	CW @ 20 wpm
	145.857	T	CW @ 20 wpm
	145.903	KT	CW @ 20 wpm
RS-11	29.407	K	CW @ 20 wpm
	29.453	KA, K, A	CW @ 20 wpm
	145.907	T	CW @ 20 wpm
	145.953	T	CW @ 20 wpm
UO-11	145.825		1200 bps AFSK ASCII (FM)
	435.025		1200/4800 bps AFSK ASCII (FM)
AO-13	145.812	B	400 bps PSK ASCII(SSB)
	"	B	50 wpm RTTY (SSB)
	"	B	CW @ 10 wpm
	435.651	JL	400 bps PSK (SSB)
	"	JL	50 wpm RTTY (SSB)
UO-14	437.025	J	9600 bps AFSK ASCII (FM)
AO-16	437.025	J	1200 bps PSK ASCII (SSB)
	437.050	J	1200 bps PSK ASCII (SSB) (primary)
DO-17	145.825		1200 bps AFSK AX.25 packet (FM)
WO-18	437.075	J	1200 bps PSK HEX ASCII (SSB)
	437.100	J	1200 bps PSK HEX ASCII (SSB) (primary)
LO-19	437.125		CW (** not currently active **)
	437.150	J	1200 bps PSK HEX ASCII (SSB) (primary)
FO-20	435.795	JA	CW @ 20 wpm
	"	JA	1200 bps PSK ASCII (SSB)
	435.910	JD	1200 bps PSK ASCII (SSB)
BADR-1	144.028		
	145.825		

Table 3 — Amateur Satellite Telemetry Beacons

Decoding FO-20 Packet Telemetry

During Mode JD operation of FO-20, 1200 bps PSK packet telemetry is transmitted. Telemetry from FO-20 is almost exactly like that of FO-12. This isn't unusual since they were built at the same time. FO-20 has had a few upgrades made to the FO-12 unit, especially to its power control system. Figure 11b is a sample of FO-20 telemetry. 8J1JBS is the packet address of FO-20, the RA says that the telemetry is realtime ASCII and the date / time group is obvious. The telemetry is sent interspersed between PBBS activity in 4 lines of 10 channels each. The data consists of 30 analog channels, three are not currently used. Thirty status points are sent in channels 30 - 39. The analog values are decimal values and taken straight into the calibration equations. The status channels are sent as octal values and then broken down into binary. The calibration equations for FO-20 are found on CIS HAMNET under FO20TL.ZIP and in the *Handbook of Amateur Satellite Telemetry*.

8. 9600 BPS AFSK ASCII Telemetry

Currently the UO-14 9600 bps AFSK telemetry is the most complex form of amateur satellite telemetry. Data sent at 9600 baud allows 6 times the data as a1 200 baud transmission in the same length of time. This means that 1000 characters could be sent at 9600 baud in the same amount of time as 167 characters sent at 1200 baud. Obviously this doesn't come easily. In addition to a special modem, the modem needs to be connected directly into the IF of the receiver and into the modulator of the transmitter. This mode is for the experimenter now, but before long we all will be able to utilize this technology. The crew at the University of Surrey with assistance from some of the AMSAT-NA gurus are again pushing the technology in the finest traditions of Amateur Radio.

Future Telemetry Formats

The variety of telemetry transmission formats and the specialized equipment required to receive satellite telemetry keep many people from exploring satellite telemetry. Technology is currently available to provide a general purpose signal conversion unit. DSP (Digital Signal Processing) will soon be widely available and will allow one piece of hardware to be able to copy nearly all digital transmissions. This includes SSTV, FAX, RTTY, PSK with Manchester encoding, even 9600 baud AFSK will be possible. The price of these units initially will be quite dear ($700 - $1000), but their versatility should make that more acceptable. The DSP units are essentially under software control and will be able to demodulate nearly anything they are programmed to do. Currently AEA, L. L. Grace Communications Products, and DRSI are working on units and plug-in boards.

Telemetry Analysis

After equipping your station, collecting the telemetry, calibrating the analog values and assigning status, it is time to begin the telemetry analysis. Analyzing the data is useful for two reasons. The first is to immediately determine when a system problem is developing. The second as a means of studying one channel, or a number of channels, and looking for patterns or inter-relationships.

To perform system monitoring, a complete set of baseline values needs to be established. Each time telemetry is captured and decoded, choose a few channels to examine. Determine what the standard value or range is for each channel. The internal temperatures should remain fairly constant. The external temperatures should stay within a fixed range. The bus voltage should be fixed, and the transmit power should maintain a fixed range. Once baselines for all the channels have been determined, only a cursory examination of the telemetry is necessary to identify abnormal conditions.

System observations using telemetry requires closer examination of the data, deductive reasoning and some creative investigation. Whole Orbit Data (data from selected channels sampled and stored for an entire orbit) offers the most complete data set. The best place to begin is to take the data for a single channel and graph it verses time. Study the graph and look for trends. Then try to explain them. Using the printouts of the decoded data, a piece of graph paper, and a fair amount of time will give you a good graph. The problem is the same thing needs to be repeated each time new data is looked at or the scale changes. This kind of operation is the reason spreadsheets were designed. By inputting the data only once, you can filter only selected channels or groups of channels and instantly graph this selected data. This may require your learning to use a spreadsheet, but I

guarantee you that you will spend much less time becoming familiar with the spreadsheet than doing 15 or 20 graphs by hand. Once you become comfortable with the spreadsheet you will be amazed at how creative you become. You can quickly manipulate the data and instantly graph it.

Figure 12 is a graph of channel 30H from the complete WOD (abbreviated in Figure 7). Channel 30H is the array current for side +X. Examining the graph, we see a series of current maximums. From the actual data we note that these occur every 8 samples. Using a sample rate of 4.84 seconds x 8 samples gives 38.72 seconds/current max. We know that when the solar cells are illuminated they produce current. This is the rate that the satellite is spinning or 1.55 rpm. We can also notice a long period from 781 to 1149 in which no current is generated. The satellite must have been in eclipse. Running the N4HY QuikTrak program, setting the date/time for 17 Aug 1990 00:00 and placing the display in fast mode we can watch when the satellite goes into eclipse. Taking the start time of the WOD from the UO11 bulletin and using the 4.84 second/sample rate we calculate the beginning of the eclipse to occur at 63 minutes after data collection begins. The no current time lasts 368 time units, so we predict that the eclipse should end at 92.6 minutes after collection begins. Returning to the N4HY program we see the eclipse flag come on at 01:02:25 and go off at 01:33:10. So the observed and calculated match very closely, and confirm our first telemetry analysis. Figure 13 is the graph of the current for all four sides simultaneously. We see the graphical representation of the power generation transfer as the satellite spins. One other observation, side +Y generates about 220 mA less current at peaks than the other three sides.

Try your hand at amateur satellite telemetry. You will find it a challenging and interesting area of satellite operation.

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SAREX Hardware Development

(Continued from page 11)

sively redesigned to accommodate the new tasks required of it by the addition of the packet and ATV functions.

Switches were added to switch from Packet to SSTV mode and to select video sources. The video source switch was required because of the need to switch from the camera to the VCR as a video source. Since the VCR also houses the color LCD monitor it had to be left connected to the monitor connector on the front panel. The camera and monitor connectors were changed to 13 pin connectors to provide the additional functions and to accommodate the 6 VDC power required for the SONY camcorder.

As can be seen by this description of the SARFX hardware, there has been no shortage of work for the SAREX team volunteers. They have all provided many hours of tireless work on this project and continue to do so.

There is still much work to be done.

The STS-37 SAREX flight should prove to be very exciting.

We will be ready! ■

Mode S: Plug and Play!

By Ed Krome, KA9LNV
1023 Goldfinch Rd.
Columbus IN 47203

A guide to getting on Mode S — it's not as hard as you think!

At the last AMSAT Annual Meeting and Symposium at the Johnson Space Center in Houston, Texas, Mode S gear was a frequent topic of informal discussion. Mode S is currently our highest frequency satellite band in use, utilizing a 2401 MHz downlink and a 435 MHz uplink. This article might well be called almost an "appliance operator's guide" to Mode S and will detail the whys and hows of this exciting mode.

Why Mode S?

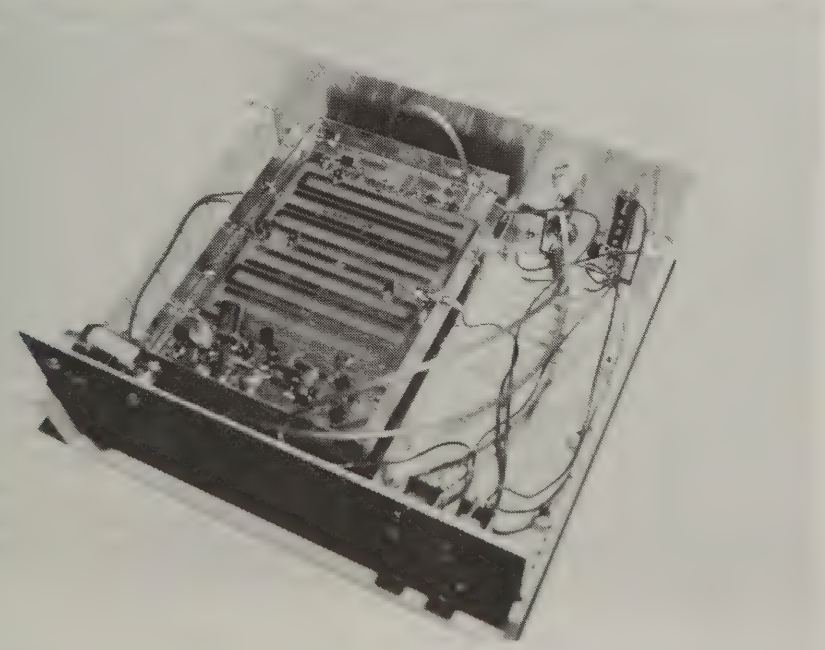
Ok, the first question, and one that deserves an answer, is "why in the world get active on a microwave band"? The second question is "why do those satellite designers keep making frequencies higher anyway"? I posed these questions to two long time AMSAT volunteers, Courtney Duncan, N5BF and Jim White, WDØE. Their comments:

1) The higher you go in frequency, the lower the background noise, and the less man-made noise. Look at Mode B, which in Japan is mostly unusable due to interference from the huge 2 meter FM population, not to mention the commercial boys. Even the wonderful 70cm is turned to hamburger by radar in certain parts of the country. Ugh. Not many 13 cm HT's around to get in the way on Mode S.

2) Space to expand (if you will pardon the pun). Our 2 meter satellite allocation is only 200 kHz wide. On 13 cm, we satellite guys get 50 MHz, and terrestrial users get even more spectrum space. More chance to accommodate more people and modes with less QRM.

3) Use it or loose it. RF real estate is extremely valuable, and the commercial people are hot for our 13cm chunk. Look at some of the proposals for WARC 1992. The best defense against losing ham bands in general is to use them. Having functioning birds already on 13cm will greatly enhance Amateur Radio's argument that this band belongs to hams.

4) High frequencies mean high gain in small antennas, both in the air and on the ground. A quite usable Mode S ground station receive antenna is less than 8 feet long and only 2 inches in diameter! Really. Do you realize that a Microsat transmit antenna is only a few inches long? Thus high frequencies keep the real estate costs down.



Mode S 13cm transverter with local osc. board shown.

Part numbers, Descriptions and Prices

Antennas:
Down East Microwave 45 element loop Yagis, W3HQT design
Kit: model 1245LYK, ($75)
Built: 1245LY, ($90)

Preamplifiers:
Down East Microwave (WA5VJB/WB5LUA "no-tune" design)
Kit: 13LNAK, ($40) No case or connectors
Built: 13LNAWP, ($140) in weather proof enclosure

SSB Electronic USA
Built: DX2400S, ($225)

Converters:
Down East Microwave (KK7B/WA8NLC "no-tune" design) All include Local Osc. and crystal.

13cm receive converter:
Kit: SHF2400K, ($150)
Built: SHF2400B, ($250)

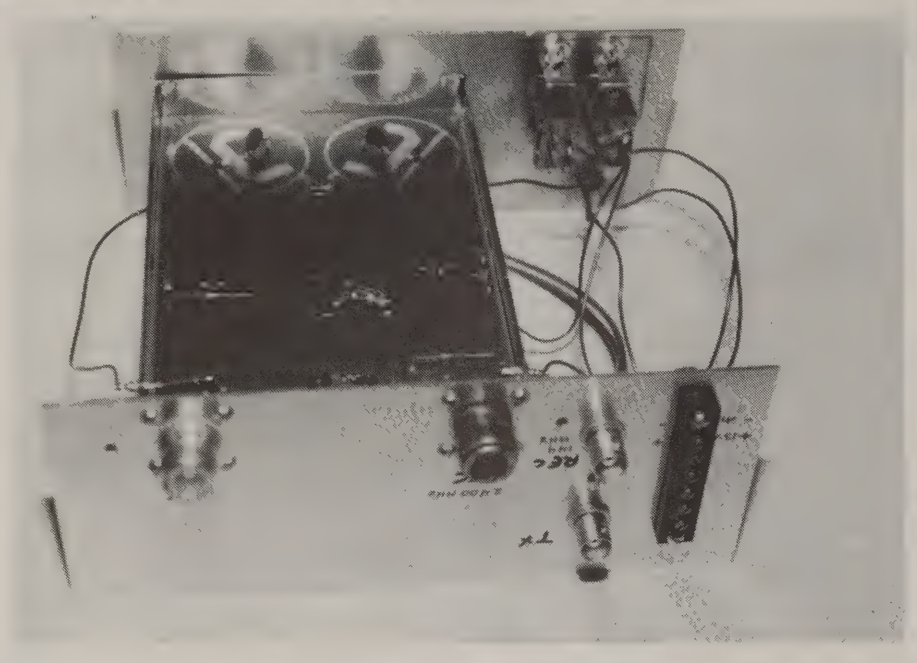
13cm transverter:
Kit: SHF2304K,($195)
Built: SHF2304B, ($310)
SSB Electronic USA 13cm receive converter
Built: UEK13P3C, ($250)

Sources:
Down East Microwave (Bill Olson, W3HQT), Box 2310 RR 1, Troy, Maine 04987
(207) 948-3741
SSB Electronic USA (Jerry Rodski K3MKZ), 124 Cherrywood Drive, Mountaintop, PA 18707
(717) 868-5643

5) Finally: Mode S's downlink is on 2401 MHz. It is much easier (and cheaper) to build receive gear for UHF bands than it is to try to generate substantial transmit power up there. In reality, Mode S is easier to get operational than is Mode L.

Mode S — Alive and Well

Currently, there are two separate implementations of Mode S on flying satellites. Two of the Microsat's, PACSAT and DOVE, have 2401 MHz telemetry beacons and AMSAT-OSCAR 13 (AO-13) has a full featured and functional Mode S transponder and beacon.



Mode S 13 cm transverter rf board shown. Design by KK7B/WA8NLC.

As of this date (November 1990), the Microsat's beacons are not operational according to a regular schedule. This can be expected to change in the near future as power budget considerations are refined. The Microsat beacons have been active enough to show that they quite loud and easy to copy. Antenna requirements are easy with medium gain and wide beamwidth being the desired characteristics. The bird's low circular orbits move them rather quickly across the sky; tracking with very high gain arrays can be challenging. The downlink signals are characterized by a very large Doppler shift, typically over 100 kHz during a pass. This has proven (in my experience) to be less of a problem than I suspected. My receive arrangement uses converters in front of a Kenwood TS430S HF receiver and a G3RUH PSK modem. Once the modem is locked on the S band beacon, the modem autotune function maintains frequency lock through the entire pass.

The AO-13 Mode S transponder has different characteristics and slightly different requirements to that of the Microsats. Both a telemetry beacon and full duplex transponder are available. Signals are much weaker than those from the Microsat's, but AO13's high elliptical orbit means slow position change and very little Doppler shift. Hence, it may be weaker, but it's easier to point at and follow. I work this transponder with a single loop yagi and preamplifier, the same arrangement I use on the Microsats. There is always a fair amount of activity up there; some stations report almost 50 different people to talk with, on the band. QSO's tend to be relaxed and congenial. And no QRM. Nice band.

How to get there

In order to show that Mode S is not the forbidden frontier is reputed to be, I brought a complete Mode S station to the AMSAT Symposium in a small suitcase: antenna, preamplifier and downconverter. Try that on Mode B.

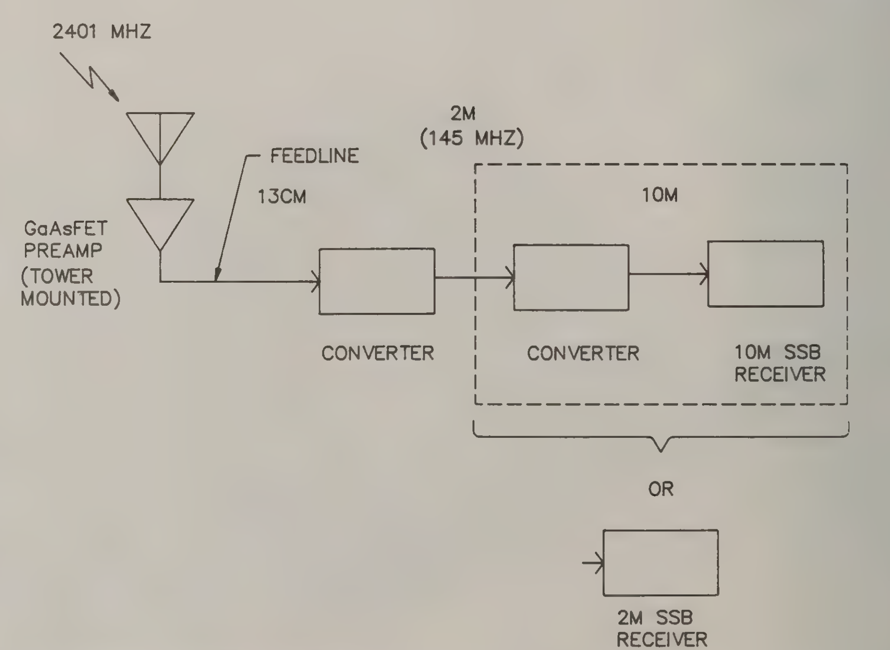
Since this article could be called the "appliance operators guide to Mode S" we will briefly review what is required for the band and where to get it. A note — Down East Microwave (Bill Olson, W3HQT) is referred to frequently for system components simply because they are the only people I have experience with who handle such things! I have no association with the company. Another source of 13cm gear is SSB Electronic, a German manufacturer. Although I have not used equipment by SSB, they are well known and have been around for a number of years. Jerry Rodski, K3MKZ, represents them.

Details

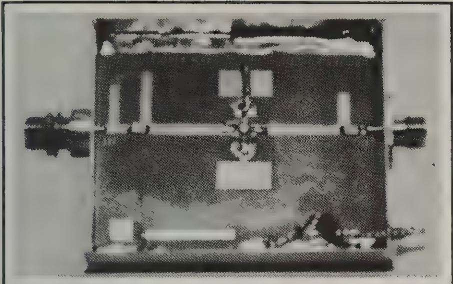
Transmit (uplink): The 435 MHz uplink frequencies and power requirements are the same as required for Mode B, so most AO-13 operators already are set on this end.

Receive (downlink): This is the part that scares people and it shouldn't. Downlink equipment required is the same as for any other band: antenna, preamplifier and downconverter. Figure 1 shows how it all fits together. Equipment for this band is almost off-the-shelf. Note that available receive equipment is in the form of converters designed to be used ahead of regular communications receivers; there are no complete 13cm transceivers available to the amateur community. Two meters is the typical IF.

All SSB Electronic gear is complete and ready to go, but Down East Microwave will supply all listed equipment in 3 forms: bare board, kit of board and parts and completely assembled and tested. Which you choose depends on your skill level and how adventurous you are. Test equipment is not required. Down East's bare boards are just



Mode S Downlink diagram. (Drawn by Terri Hurd.)



Mode S 13cm GaAsFET preamp. (design by WB5LUA/WA5VJB).

that — circuit boards and schematics. These are mostly for those who have huge junkboxes or for those wackos (like me) who couldn't bear the thought of not being intimately involved with their equipment. Components, connectors and cases are up to the discretion of each builder. The second level is the complete kit of parts. These are more like magazine articles with boards and parts. These are the best bet for homebrewers because some of the parts can be quite difficult to find (No, Radio Shack does not yet carry ATF10135 GaAsFET's). Same caveats as bare boards, including no case or connectors. The kits really are pretty easy to build. The third version is ready-to-go, complete with cases and N connectors. This is truly the plug-and-play stuff. Take your pick.

Some comments on the various pieces are in order.

Antennas: Down East appears to be the only source of ready made or kit antennas. These 45 element loop yagis come with short UT141 hardline feed lines and N connectors. One is adequate for the Microsat beacons (which are loud) and usually adequate for AO-13 (which is not loud — a good preamplifier is a must). Down East makes versions for both Mode S (2401 MHz) and for the 13cm ham band (2304 MHz). The gain of the 2304 version will roll off considerably before it gets to 2401 MHz and it may be less than adequate for AO-13. Get the right one. I have not used one of these personally, but they certainly appear to be the standard on the band. (I use a homebrew 52 element loop yagi cut for 2350 MHz which works). If more downlink signal strength is desired, stacking frames and power splitters are also available. A pair of these will be great on AO-13, but will make manually tracking the low and fast Microsat's rather challenging. Start by using one antenna.

Preamplifiers: The preamplifier must be mounted at the antenna feed point. Even a few feet of feedline can make a difference. The best place to mount one is on the antenna boom connected directly to the antenna feed. Be sure to support the preamplifier adequately, which means don't just use the connector alone, use some sort of mounting hardware. Even if the preamplifier and antenna are left connected all the time, the all metal construction of the loop yagi prevents GaAsFET-killing static buildup, as long as the yagi is at DC ground. Southern Indiana has some roaring thunder and lightning shows, and my preamplifiers have survived just fine.

Down East's preamplifiers are "no-tune" impedance matched designs using ATF10135 GaAsFETs, designed by Al Ward, WB5LUA, and Kent Britain, WA5VJB. They typically have less than 1 dB noise figure and 10+ dB gain. The ready-to-go unit is housed in a weatherproof die cast box and has N connectors.

SSB Electronic's preamplifier is a 2-stage (GaAsFET + bipolar) device with a .8 dB NF and 20 dB gain. It is housed in a weatherproof die-cast box and has N connectors for both input and output.

Feedline: Feedline from the preamplifier to the shack should be as good as you can afford. For a 100 foot run, I would consider Belden 9913 as a minimum with hardline preferred. Another approach to dealing with a long feedline is to series connect two preamplifiers; one mounted on the antenna boom and the second close by on the tower. Olson also has built some 2-stage preamplifiers that would probably be excellent since they have 20 dB gain.

Downconverter: KK7B and WA8NLC have developed a series of "no-tune" transverter boards for 902 through 5675 MHz and they are simply amazing. They use MMIC's and printed hairpin filters and have no tuning adjustments possible. This results in a 13cm rig that works the first time without test equipment, unbelievable but true. These boards are quite easy to build, but do require reasonable patience and care. Two versions are available. One is a complete transverter (which I recommend; adding a second crystal to the local oscillator will allow operation on the 2304 MHz band.

(Continued on page 25)

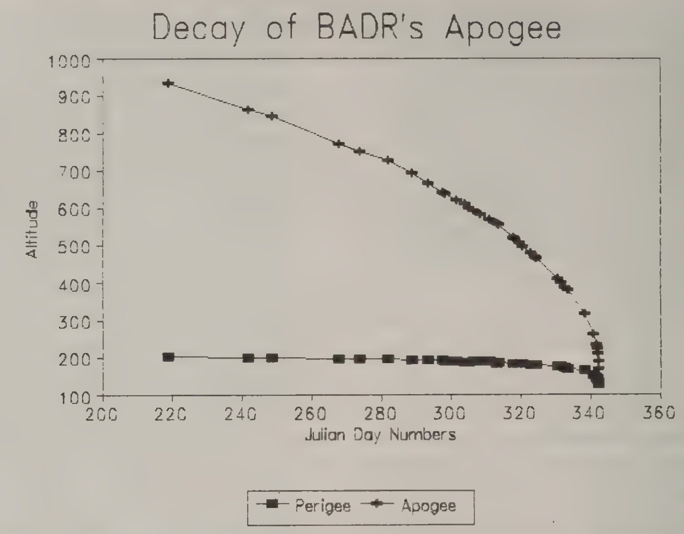
BADR-1 DECAY

By Richard Ensign, N8IWJ

Pakistani "Amateur" Satellite Re-enters Earth's Atmosphere.

BADR-1, the Pakistani satellite launched by the People's Republic of China earlier this year re-entered the Earth's atmosphere either late on 8 December 90 or early on 9 December 90. The satellite transmitted on a downlink frequency of 145.825 MHz, a frequency also used by UoSAT-OSCAR 11 and DOVE-OSCAR 17.

It was never quite understood why the Pakistani Government assigned the 145.825 MHz output frequency when there was no amateur transponder on-board or any published telemetry information which might have been of use to the Amateur Service.



1990 DAY	PERIGEE (KM)	APOGEE (KM)	ECCEN-TRICITY	PERIOD (MIN)	DECAY	MEAN MOTION (ORBITS/DAY)
219.0	203.6	934.8	0.0526	96.05	0.0023	14.99
241.8	200.2	865.2	0.0481	95.3	0.0026	15.11
248.5	200.3	846.1	0.0468	95.1	0.0023	15.14
267.8	197.3	771.8	0.0418	94.3	0.0037	15.27
273.8	196.4	751.4	0.0405	94.1	0.0027	15.31
281.8	195.2	725.1	0.0387	93.8	0.0033	15.35
288.7	193.8	691.3	0.0365	93.43	0.0046	15.41
293.4	191.9	666.3	0.0348	93.12	0.0051	15.46
297.4	190.8	642.6	0.0333	92.90	0.0053	15.50
298.4	189.9	637.2	0.0329	92.78	0.0056	15.51
301.4	189.2	619.3	0.0317	92.65	0.0054	15.54
304.1	184.7	608.2	0.0313	92.49	0.0050	15.57
305.1	184.8	602.0	0.0308	92.43	0.0051	15.58
306.3	187.7	593.2	0.0299	92.37	0.0048	15.59
308.2	187.8	583.6	0.0290	92.32	0.0045	15.61
311.0	186.9	569.1	0.0283	92.11	0.0048	15.63
313.0	184.0	559.3	0.0277	91.98	0.0054	15.65
313.5	185.1	554.5	0.0274	91.98	0.0057	15.66
317.7	183.5	521.7	0.0251	91.59	0.0072	15.72
318.3	183.3	517.3	0.0248	91.55	0.0068	15.73
319.6	182.3	507.0	0.0241	91.43	0.0074	15.75
320.6	181.6	499.6	0.0237	91.35	0.0078	15.76
322.9	180.1	479.1	0.0223	91.12	0.0083	15.80
323.9	179.4	470.5	0.0217	91.03	0.0082	15.82
324.6	178.8	464.9	0.0214	90.97	0.0081	15.83
330.6	174.9	410.0	0.0176	90.36	0.0095	15.93
331.6	173.8	400.4	0.0170	90.26	0.0102	15.95
332.6	172.8	388.3	0.0160	90.13	0.0114	15.98
333.4	168.9	382.3	0.0160	90.03	0.0107	15.00
338.3	163.4	315.8	0.0120	89.29	0.0161	16.13
340.8	152.1	261.0	0.0080	88.63	0.0372	16.25
341.6	145.3	235.5	0.0069	88.30	0.0481	16.31
341.8	142.6	223.3	0.0061	88.15	0.0585	16.34
342.05	139.7	208.5	0.0052	87.97	0.0657	16.37
342.3	131.5	187.7	0.0043	87.68	0.1185	16.42
342.4	126.8	169.8	0.0033	87.45	0.2155	16.47

Here is a history of BADR-1's brief life in orbit as seen through its element sets. Its decay is a classic case of orbit circularization. Most of the decay went in to dropping the apogee. Once the apogee dropped to 200 km it was bye-bye birdie.

Data sources are the NASA element sets supplied by the ANS and at more frequent intervals by Ed O'Grady. Derived elements were obtained using QUIKTRAK 4.0 with the time set to the element set epoch. ■

AMSAT APPLICATION NOTES:

Portable UO-14 Station

By Jeff Ward, GØ/K8KA

After a bit of playing around (mostly with the antennas), I have used a simple, portable groundstation to upload and download messages to and from UoSAT-OSCAR 14 (UO-14) at 9.6 kbps.

Other than the antennas, the station fits in a metal carrying case about the size of a small briefcase. The RF gear (built by G0/VE3LMX in the UoSAT Lab) uses single-channel FM receiver and transmitter strips from Wood & Douglas with minor modifications. The transmitter generates 10W output, and no Doppler steering was used. The receiver has a daughter board with an automatic frequency control (AFC) circuit. This AFC sweeps the entire Doppler band until it detects the satellite, allowing for unattended operation.

For the TNC and modem, we use a TINY 9600 from Pac Com; the modem is added to the TNC as a daughter board and the whole thing is in the standard small extruded TNC case.

The receive antenna is a 1.5 turn helix sitting on the ground pointed just a bit north of straight up. For transmitting I started with a 1/4 wave groundplane but had little luck. The next saturday evening I took home a 137 MHz turnstile from our weather satellite station. This sits perhaps a meter above the ground, pointing straight up.

So as not to alarm my landlords, I put the antennas very close to the house. They are completely blocked to the south and west, but look fairly clear to the north and west. I reckon this is a good simulation of a real portable or emergency site in an urban area.

Late that same saturday, using the turnstile for transmitting, I got excellent results on a 60 degree pass east of my location. I managed to connect to the FTL0 BBS server, get a directory, upload my message to Harold, NK6K, and download about 16 kbytes in connected mode. Then I switched to the broadcast protocol, requested and received an AMSAT Keplerian element file, and played around a bit more. The following morning, I downloaded Harold's reply.

The station seems to work better on the downlink than on the uplink. If there had been bulletins or ANS on the broadcast downlink, I could probably have received a hundred Kbytes of data on any pass with a minimum of 10 degrees elevation.

The uplink suffers from interference and from using antennas so close to the ground. There is plenty of terrestrial activity on our uplink channel. Listening in analogue repeater mode we often hear full-quieting FM voice stations from the continent *(Ed. note: Europe)*. The pattern of the turnstyle may not be quite according to theory, since it is located so close to the ground.

These are the first portable groundstation tests conducted outside of the UoSAT lab. I was encouraged that $200 worth of RF gear and some cheap antennas could provide useable 9.6 kbps/sec satellite packet service. ■

Mode S: Plug and Play!

(Continued from page 23)

We need all the activity on that band we can. 2304 MHz transceive capability will also make you very popular at contest time.) The second version is a receive only board, which is basically half of the transverter board. Both require a separate Local Oscillator, which is included in the kit and built-up versions.

SSB's converter is a ready-to-go narrow band unit with a GaAsFET front end and active mixer. It has an integral Local Oscillator. Dual frequency operation (2401 and 2304 MHz) is not possible without retuning.

IF section: These converters use a 2-meter IF, which can be either a 2M multimode transceiver (receiver) or a 2M to 10M converter followed by an HF receiver. If you use a transceiver, be sure you can't accidentally transmit into the receive converter. Once you let all the smoke out of your converter, it won't work anymore. Listen to the voice of experience.

That's It!

Buy the complete antenna, preamplifier and converter and plug and play on Mode S. Or, for a little work (and considerably less money), build up the kits and get the satisfaction of knowing what is going on inside that box. Good luck. ■

OSCARS IN THE CLASSROOM

Conducted by:
Richard C. Ensign, N8IWJ,
AMSAT Science Education Advisor
421 N. Military
Dearborn, MI 48124

One of my jobs as your Science Education Advisor is to get you thinking about how you can share the exciting world of Amateur Radio (AR) satellites with educators in your community. In this column we hope to give you some ideas on how to implement AR satellites in your local schools and to begin a free flow of exchange between you, the satellite users, as to what works in activating teachers and classrooms. We'll also be reporting on some success stories where satellites have been successfully integrated into local curricula. We begin with one of these success stories as Ann Strieby, student secretary of her physics class reports on how her class uses BRAMSAT-DOVE OSCAR 17.

Dave Reeves, Ann's teacher, has been very active in promoting Amateur Radio satellites in the classroom through presentations at National Science Teachers Association meetings in California and also in various educator publications. Dave has also written several physics lab exercises in which the speed of light is measured using the RS 10/11 CW beacon and LUSAT's CW beacon. The measurement of the Doppler effect and the application of vector analysis to the satellites velocity brings the student to a measurement of C, the speed of light. Dave will be happy to supply you with copies of these labs. Write him at the address below in Ann's article.

One of my greatest joys is the editing and distribution of the *AMSAT EDUCATION (AE) NEWS*, a monthly newsletter which is distributed internationally with the major part of the overseas subscriptions going to Germany, England and Australia. *AE NEWS* is for educators who are not necessarily hams. Activities and approaches for students of all ages are included. The publication is heavily oriented towards teacher introduction to our hobby and what you can do with our satellites. We have emphasized the "where to get it, how to do it approach" and encouraged teachers to contact their greatest resource, local hams and Amateur Radio Club's (ARC). Would you or your ARC like to subscribe or get a subscription for a teacher locally? The donation rate for 1 year (10 issues) is $5.00 USA, $7.00 Canada, and $10.00 overseas. Write or call AMSAT HQ to subscribe.

What are your thoughts about satellites in the classroom? Write and let us know. We'll be happy to share your thoughts through this column. I am especially interested in your classroom demonstration ideas and experiences. Next time we'll explore the SAREX experience in several classrooms. ■

CHAMINADE STUDENTS RECEIVE TELEMETRY FROM DOVE

By Ann Strieby

My senior high school physics class at Chaminade Preparatory School in West Hills, California is monitoring information from the BRAMSAT Satellite DOVE under the supervision of our teacher, David Reeves, KF6PJ. During each pass that we monitor, we receive 15-16 pages worth of 59 channels of data. The information includes temperatures, currents, voltages, etc. New Keplerian element sets tell our Commodore 64 where the satellite is, making it possible for our satellite rotary antenna to point at DOVE during the overpass (we are presently constructing a J antenna to prevent overuse of the rotary antenna). Using the "What's-Up" by Joe Kasser, G3ZCZ, we are able to decode and display DOVE's information (telemetry) on a PC computer. Each day, many of us take part in collecting the data from DOVE and translating it. Steve and Brian, fellow students of mine, come to the lab in the morning to make the overpass predictions for the day. There are 6 overpasses during each 24 hour period but we only collect data from the 3 passes during the day. Keith and Ben can be credited with operating the antenna (this antenna was built by Mr. Tweedy) and the receiver, and actually receiving the data. Grace and Dana have made charts from the data telling us how DOVE moves. These charts have been distributed to everyone in the physics classes involved in the satellite. Everyone can get a feeling for what DOVE looks like by viewing the full scale model of the satellite that was built by Joe and Paul. We are having a lot of fun with DOVE and wish for you to share our enthusiasm.

Ann Strieby, Senior, Chaminade Preparatory School, 7500 Chaminade Ave., West Hills, CA 91304, USA. Amateur Radio Club Station, WA6BYE.

AMSAT NEWS:

AMSAT QSL Bureau Alive and Well; Needs Your QSL Card and S.A.S.E.

WB8OTH wishes to remind all OSCAR satellite users that as Manager of the AMSAT QSL Bureau, he needs your SASE! Perry says that he has many QSL cards waiting for hams to receive but he can't forward them because of the lack of envelopes from addressees. Perry adds that everyone who uses OSCARs, especially with the increase in DX activity seen on AO-13, should send him their outbound cards along with several SASEs so he can quickly turn around that rare DX QSL. Send your QSL cards and SASEs to following address:

AMSAT QSL BUREAU
1850 Lise Avenue
Obetz, OH 43207-4443

WO-18 Report, Dec 21,1990

We've been continuing experiments with the camera the past two weeks. In an attempt to characterize all experimental artifacts inherent in our CCD, we have taken several images in the dark. Additionally, a

number of iris parameter values were uploaded in the past few days to use in shooting more pictures of the Earth. Unfortunately, one often must wait several days to get high confidence results from these iris experiments because the lens is seldom looking down during magnetic equator crossing.

One faculty member here has proposed a theory concerning the slower rotation of the spacecraft which seems to have merit. It is based on several NASA documents where problems with attitude control of non-symmetrical spacecraft are described. His conclusions will be presented in an article in the *Journal*.

New software is being prepared for upload in which the spectrometer experiments will be supported. Because of the intricacy of the code and the danger to the spacecraft involved (the spectrometer has high power consumption), we are testing this version of the Flitepic software thoroughly. Once aboard, all experiments of the spacecraft will be supported for use. We estimate we're several weeks from upload. — Chris, WA3PSD

AREM Equipment Nearing Completion

The equipment for the Austrian Amateur Radio Experiment on MIR (AREM) is nearing completion. In a telephone interview for the South African Radio League programme "Amateur Radio Mirror" the President of AMSAT-OE, Wolf Hoeller, OE7FJT, said that integration of the equipment is nearing completion. The packet radio station consists of a TNC2 and a two meter hand-held transceiver built into a "black" box with connectors for the antenna and labtop computer.

He told Hans van de Groenendaal, ZS6AKV, that the TNC and radio will be delivered to Moscow by mid January for a month of testing. The equipment will be sent to MIR during early March.

For the first few months AREM will operate as a Packet radio beacon. During a later supply mission a labtop computer will be sent to MIR which will allow the cosmonauts to program messages. Wolf, OE7FTJ, said that there is some doubt whether the laptop computer will survive the shake test. It may well have to be taken up by an Austrian Cosmonaut due to be sent to MIR toward the end of September or in early October, 1991.

The packet radio beacon will be operating on 145,990 MHZ.

— Thanks ZS6AKV

AO-16 Experimenters Day Announced

In the tradition of AMSAT's Wednesday Experimenters Day, AMSAT and the PACSAT command team announce the routine operation of AO-16's S-Band (2401.143 MHz) and raised cosine (437.050 MHz) PSK transmitters starting Jan. 16, 1991. Since the operation of these transmitters is currently under ground control, the start and stop of their operation will not occur exactly on Wednesday UTC but will vary a few hours either way. While operation of the S-Band and raised cosine PSK transmitters is scheduled to be conducted weekly, users are cautioned that these operations may be shortened or canceled to allow uploading of improved spacecraft software. Watch for bulletins in the BBS and the telemetry text frame of AO-16. Users are requested to send reception reports and comments for the January operations to WB9ANQ:@PACSAT-12,@W8BI.OH.USA.NA, or via CompuServe to 74017,2454. *— Thanks WB9ANQ.*

NEW AO-13 TRANSPONDER SCHEDULE

The new winter transponder schedule for AO-13 is as follows:

Mode-B:	MA 0 to MA 165	IF eclipses over-drain battery in
Mode-JL:	MA 165 to MA 190	Jan 10 - Feb 06, B-OFFs MA 20-65
Mode-LS:	MA 190 to MA 195	
Mode-S:	MA 195 to MA 200	Mode B is OFF; no swishing!
Mode-BS:	MA 200 to MA 205	QRP on BS please. High power
Mode-B:	MA 205 to MA 256	wipes out Mode S experimenters.
Omnis:	MA 240 to MA 30	

This schedule is expected to span from 28 December 90 to 25 March 91. The command team requests that you make a specific effort to use QRP on Mode B between MA 200 to 205. This is specifically to help those people who are experimenting with Mode S.

Magnetorquing operation is expected to take place during the week of 24 December 90. This operation takes place during the portion of the orbit closest to perigee (MA 000) and is done primarily to reorient the spacecraft for improved solar panel illumination. During magnetorquing, the transponders will be off (typically between MA 220 and MA 60).

During the Winter, the worst Sun angle (11 March 91) will be -27 deg, resulting in 89% illumination. AO-13 will experience eclipses by the Earth from 11 January 91 to 6 February 91, the longest being 82 minutes (MA 32-53).

If battery drain is excessive during this period of time, it may result in Mode B being turned off during MA 20-65 until 6 February 91. AO-13 will experience Lunar eclipses on 16 March 91 (50%) and 14 April 91 (23%).

Once magnetorquing operations have been completed, the spacecraft attitude of AO-13 is expected to be:

BLON = 210.0 and BLAT = 0.0 for 31 December 90.

Spin Rate should be brought up to 30 RPM from the present 27.6 RPM.

AMSAT-OSCAR 10 appears to be receiving sufficient solar panel illumination to support Mode B transponder operations. The transponder may be used, carefully, at all points of the orbit except MA 254 - 006 when eclipses occur. If beacon or transponder signals show signs of FMing, users should cease all transponder use immediately. An APPROXIMATION of the spacecraft attitude for AO-10 is :

BLON = 2.0 and BLAT = 0.0 for 29 December 90.

WØSL Appointed AMSAT-NA Software Exchange Manager

AMSAT-NA VP for Operations, Courtney Duncan, N5BF, announces the appointment of Roy Welch, WØSL, as AMSAT-NA Software Exchange Manager, effective on January 14, 1991. Roy has been an active Amateur satellite user for many years, is an AMSAT Area Coordinator, and is author of one of the first satellite tracking programs for IBM-PC and compatible systems called "Orbits."

Roy's appointment comes at an exciting time in the world of Amateur Radio satellites. Several different types of software including satellite tracking programs, telemetry analysis programs, scientific and educational programs of various sorts, and now PACSAT ground station software are handled by AMSAT-NA in support of several different types of personal computer systems. With the assistance of other volunteers specializing in various systems or software types, Roy will be overseeing the AMSAT software process from authors to final production and distribution.

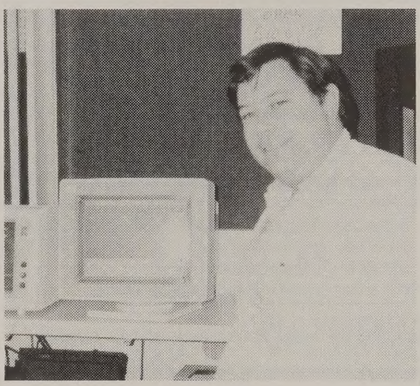
If you have questions about the software that AMSAT has available or would like to volunteer to write programs or participate in some other way in the process, please contact:

Roy Welch, WØSL
908 Dutch Mill Drive
Manchester, Mo 63011.

1990 AMSAT Space Symposium and Annual Meeting

(Continued from page 5)

tions organization met for breakfast to review the past year's accomplishments and plan for the 1991's Field Ops activities which are to include a stronger presence at local hamfests around the country. Four additional presentations were made primarily focused towards beginners interested in getting started in operating on the OSCARs. For those who had flights home later in the afternoon or evening, a tour was arranged



Gerry Creager, N5JXS, was one of the many volunteers from the Johnson Space Center Amateur Radio Club who helped make the AMSAT Annual Meeting and Space Symposium a huge success.

of the world's largest EME (aka OSCAR 0) two meter array. Dave Blaschke, W5UN, and his wife hosted upwards of 40 visitors to their home on a rainy Sunday afternoon. After the visitors inspected the 48 Yagi array (32.5 dB gain), Dave demonstrated armchair copy of SSB signals off the moon. Dave was presented with an AMSAT award for his efforts in resetting DOVE (DO-17) earlier in the year. Junior de Castro, PY2BJO, (President of BRAMSAT and the Father of DOVE) offered Dave special thanks in bringing his bird back to life.

AMSAT wishes to thank again Bill Tynan, W3XO, and the JSC ARC (W5RRR) and all the volunteers for their efforts in organizing and executing this year's Symposium. If you have never attended an AMSAT Space Symposium, you are truly missing an exciting and stimulating event. Leave your calendar open for the Veteran's Day weekend in November of this year. Look to *The AMSAT Journal* and AMSAT News Service for further information later this year on the 1991 AMSAT Space Symposium and Annual Meeting. It is sure to be every bit as exciting and informative as this one was. ■

MINUTES OF THE AMSAT BOARD OF DIRECTORS (BOD) MEETING

19 October 1990, Houston, TX

The meeting was convened at 9:30 AM on October 19, 1990 at the Ramada King's Inn. Those Board members present were: John Champa, K8OCL, Tom Clark, W3IWI, Jan King, W3GEY, Doug Loughmiller, KO5I, Andy MacAllister, WA5ZIB, Bob McGwier, N4HY and Bill Tynan, W3XO. The following notes document the meeting.

I. Minutes of BOD Meetings

Moved by N4HY and seconded by W3XO that AMSAT publish all Board Of Directors proceedings as minutes in *The AMSAT Journal.* This motion passed unanimously.

II. General Manager (GM)

Financial Report by General Manager Doug Loughmiller, KO5I:

Monthly average income comparisons are favorable. Revenue source analysis was conducted. Negative impacts - Microsats not fully operational and the delay of SAREX.

After a performance review of the General Manager by the BOD, the BOD voted to accept the General Manager Review Committee's Report with grateful thanks.

In addition it was moved by N4HY that in so far as the old BOD did not meet in August and did not give KO5I the necessary direction that the deadline for the business plan and five year plan be moved to December 15th. The vote was 6 in favor; one abstention.

The BOD voted 6 in favor; 1 abstention that the signed document (fax - Tmail message MGJA 4268-3131) be accepted as the contract for the GM but directed the Corporate Secretary to deliver a countersigned copy to the GM and BOD.

The GM was requested to submit with the budget, necessary reasonable funding to employ a qualified Administrative Assistant for the AMSAT-NA GM office in Paris, TX.

The BOD voted to continue the General Manager Review Committee consisting of W3XO, N4HY and W2RS in order to draft a 1991 contract for the GM, including salary and other managerial duties as needed.

III. Election of Officers

The following slate of officers was elected to a one year term by the BOD:

Doug Loughmiller, KO5I - President; John Champa, K8OCL - Executive V.P.; Courtney Duncan, N5BF - V.P. Operations; Jan King, W3GEY - V.P. Engineering; Art Feller, KB4Z - Treasurer; Martha Saragovitz - Secretary.

The BOD approved an organizational chart of appointed positions as presented by the President. Those appointments included (in addition to the officers elected above):

Senior Vice President - Ray Soifer, W2RS

Vice President Special Projects - Drew Deskur, KA1M

Vice President User Services - Andy MacAllister, WA5ZIB

Vice President Field Operations - Jeff Wallach, N5ITU

Vice President Manned Space Programs - Bill Tynan, W3XO

Vice President Publications (No appointment made)

W3XO suggested that the appointees write their job descriptions and submit them to the President for review and acceptance.

IV. Future Technical Projects

SEDSAT - Dennis Wingo. Some funding through the government of Taiwan. Availability of thermal/vacuum testing facility.

Needs support in Mode A & J transponders and help with making operating system software and command control uplink software compatible with Microsat.

First flight would be Nov 92; 2nd flight April 93. Deadline for completion of the satellite is June 1, 1992. Not looking for money from AMSAT. For AMSAT participation, the BOD required SEDS to submit design review plans and documentation for evaluation and submission of a budget for DOUG (Detroit OSCAR Users Group) and plan for the spacecraft lab.

ITAMSAT - Dr. Alberto Zagni, AMSAT Italy

- CPU drawings provided.
- Working on higher mass memory 2M.
- BCR
- CPU/BCR working together. Now getting battery into frame.
- Complete Microsat should be working by the end of the year.
- RF work has been completed. Launch - Ariane 1993 or with SEDSAT on Delta Lone Star - Bill Tynan
- Transponder requested for Amateur Satellite Service on shared mission with 2.5-2.7 GHz education satellite allocation.
- Geostationary satellite to be located somewhere between 90-110 degrees W.

PUIDE- David Lieberman - AMSAT Mexico

- No cost to AMSAT.
- Not a communications satellite.
- TSFR, scientific experiments involvement with future missions.

Microsat - Australia - Information presented by Jan King from a letter by Greg Linsey.

Phase IIID - Karl Meinzer $600K from the German government toward the project. Launch on an Ariane 5 being negotiated for 1995 time frame. ESA has informally approved the launch. Possible higher perigee (250-300km) than previous GTO launches. May 1991 meeting - will collect ideas about design.

- Mode B transponders in high demand from AMSAT-NA members. Project must be one of true international team work.
- It was moved by Bob McGwier and seconded by Jan King that based on a presentation by Karl Meinzer, DJ4ZC, and a report by AMSAT-NA participants at the Phase IIID kickoff meeting that AMSAT-NA adopt a major satellite project to produce a global coverage long access time satellite with our international partners with initial funding of $50,000. The motion passed unanimously.

V. 1991 Annual Meeting Site

Four locations have been proposed for the 1991 Space Symposium: Los Angeles, Orlando/Miami, Denver and Washington, DC. The President will study the proposals and

make a recommendation to the BOD by the end of the year.

VI. Ballots

The BOD voted to have the ballots and meeting announcement mailed separately from *The AMSAT Journal*. The motion passed unanimously.

VII. Phase IV

Moved that the Phase IV project to develop a dedicated geosynchronous satellite of our own is an impractical goal at this time and that further development should be dropped. The vote was all in favor.

VIII. Deep Space Facility - Colorado

The BOD voted unanimously to have a special committee consisting of Jan King, John Champa and Ray Soifer study the Deep Space Facility proposal and negotiate a counter proposal to NTIA.

The amount of $3,000 for repair of the physical facility was approved for 1991.

IX. Resolutions

AMSAT-NA expresses its thanks to Dennis Wingo and pledges its continued interest and involvement with the design review for SEDSAT-OSCAR. In addition it encourages the AMSAT-DOUG to participate in SEDS hardware.

AMSAT praises Bill Clapp, Bob Twiggs and Weber State University for their innovative approach on ADSAT and hope Weber and AMSAT continue their long-term cooperation, with us offering assistance on ADSAT and further that we give them help in preparing their presentation for Weber State University to sponsor ADSAT to NASA.

AMSAT commends Alberto Zagni and AMSAT-I for their creative and innovative work on continuing the Microsat legacy. We express gratitude to them for developing an alternate CPU and hope for the continued success of their project.

AMSAT thanks Arcadio Povedo and Dave Lieberman for their presentation for the planned creative use of Microsat. We look forward towards the continued collaboration between AMSAT , the autonomous University of Mexico and PUIDE. The President is authorized to negotiate a Memorandum of Understanding (MOU).

AMSAT thanks Graham Ratcliff and AASEG (Australian Amateur Space Engineering Group) for the material that they provided to us indicating their desire to work on Microsat class satellites and we direct our President to begin forming a MOU with them.

AMSAT thanks Mr. Emerson LaBombard for his interesting presentation on the recent developments in the solar sail race, and indicate AMSAT's continuing interest in working with WSF if this mission does come to fruition.

X. WARC

BOD voted to allocate $10,000 for WARC 1992 preparation activities during the time period Oct 1990 - April 1991.

Doug Loughmiller, KO5I.

A copy of AMSAT's 1990 financial report is available from the office in return for a 9 by 11 (inch) envelope. ■

Satellite Orbital Elements

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AO-10
1 14129U 83 58  B 90356.51445136 -.00000108  00000-0  00000 0 0  6304
2 14129  25.9183 168.6928 5967533 202.9623 113.0649  2.05882900 28614
UO-11
1 14781U 84 21  B 90364.62968659  .00001340  00000-0  25249-3 0  8968
2 14781  97.9252  50.5452 0012778 349.8055  10.2899 14.66016601364741
RS-10/11
1 18129U 87 54  A 90364.83596683  .00000149  00000-0  15278-3 0  4765
2 18129  82.9244 183.2363 0010759 297.5130  62.4909 13.72133042176412
AO-13
1 19216U 88 51  B 90364.23183531  .00000027  00000-0  99999-4 0  2305
2 19216  56.8519 118.2211 7095980 243.7143  29.7057  2.09698404 19511
UO-14
1 20437U 90  5  B 90361.18508633  .00000454  00000-0  19596-3 0  2868
2 20437  98.6871  76.5906 0011296 314.9270  45.0972 14.28828808 48429
AO-16
1 20439U 90  5  D 90361.65134047  .00000371  00000-0  16311-3 0  1843
2 20439  98.6894  77.2751 0011102 314.7480  45.2798 14.28925664 48492
DO-17
1 20440U 90  5  E 90359.11967090  .00000406  00000-0  17636-3 0  1834
2 20440  98.6865  74.7783 0010790 321.3692  38.6723 14.28982888 48136
WO-18
1 20441U 90  5  F 90362.66779777  .00000345  00000-0  15254-3 0  1849
2 20441  98.6892  78.3532 0011811 312.3442  47.6739 14.29063322 48644
LO-19
1 20442U 90  5  G 90359.36064767  .00000320  00000-0  14229-3 0  1832
2 20442  98.6876  75.0967 0012082 320.8594  39.1713 14.29133556 48179
FO-20
1 20480U 90 13  B 90363.01335131  .00000019  00000-0  72005-4 0  1780
2 20480  99.0197  12.5536 0540758 327.2364  29.6236 12.83166627 41732
NOAA 9
1 15427U 84123  A 90362.25961523  .00000357  00000-0  21309-3 0  6877
2 15427  99.1719   6.6760 0015058 180.9562 179.1577 14.12764946311389
NOAA 10
1 16969U 86 73  A 90360.27441756  .00000445  00000-0  21114-3 0  5338
2 16969  98.5827  23.7740 0014525  71.9543 288.3209 14.23838301221944
Meteor 2-16
1 18312U 87 68  A 90364.87026540  .00000220  00000-0  18868-3 0  5925
2 18312  82.5547 134.4132 0013679  62.3310 297.9233 13.83711471170185
Meteor 2-17
1 18820U 88  5  A 90365.07518123  .00000112  00000-0  94939-4 0  4403
2 18820  82.5434 193.9355 0017093 127.2199 233.0472 13.84406069147423
Meteor 3-2
1 19336U 88 64  A 90364.89200427  .00000020  00000-0  38677-4 0  6930
2 19336  82.5416 138.2707 0016513 178.9374 181.1795 13.16907704116843
NOAA 11
1 19531U 88 89  A 90359.31622358  .00000367  00000-0  22176-3 0  4394
2 19531  99.0083 308.0795 0013070 104.8861 255.3762 14.11838969115930
Meteor 2-18
1 19851U 89 18  A 90364.66481083  .00000191  00000-0  16196-3 0  3922
2 19851  82.5212  71.9302 0014454 167.9167 192.2346 13.84043196 92741
Meteor 3-3
1 20305U 89 86  A 90364.69418209  .00004902  00000-0  12902-1 0  3020
2 20305  82.5494  79.4230 0015314 197.7681 162.2854 13.15966319 56791
Meteor 2-19
1 20670U 90 57  A 90360.83798985  .00000125  00000-0  10180-3 0  1400
2 20670  82.5455 135.7527 0017243 105.7961 254.5105 13.83886986 25168
Feng Yun1-2
1 20788U 90 81  A 90360.67381739  .00000387  00000-0  28347-3 0   823
2 20788  98.9343  32.7980 0010405 306.6667  53.3619 14.00608869 16057
Meteor 2-20
1 20826U 90 86  A 90360.99525211  .00000290  00000-0  25488-3 0   906
2 20826  82.5262  74.8415 0014115   9.2052 350.9363 13.83255385 12403
Salyut 7
1 13138U 82 33  A 90364.87353798  .00210398  00000-0  47683-3 0  7031
2 13138  51.5943  11.0213 0003444  35.4900 324.6252 15.96477763495860
Mir
1 16609U 86 17  A 90364.59303062  .00035160  00000-0  40445-3 0  1733
2 16609  51.6107  61.2892 0025439  64.5475 295.8107 15.61259779278771
HST
1 20580U 90 37  B 90361.65399883  .00003685  00000-0  39848-3 0  3771
2 20580  28.4691  97.6195 0004974 331.5168  28.5135 14.85801902 36769
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The New IC-970

Designed for the serious operator on 144, 440 and 1200MHz, ICOM's IC-970 brings futuristic technology to DX, digital and satellite communications.

Versatile Communications.
The IC-970 comes fully equipped as an all mode dual bander for 144MHz and 440MHz. Expand your limits on 1200MHz with the optional UX-97 band unit or listen to the world with the UX-R96 50—905MHz receive unit.

Satellite Communications.
Reach beyond the stars, communications via satellite has never been easier. The amazing IC-970 automatically tracks uplink and downlink frequencies as the tuning control is rotated. Ten memory channels specially designed for quick satellite communications emphasize ICOM's total commitment to your future communications needs.

Progressive Quality Throughout.
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CORPORATE HEADQUARTERS
ICOM America, Inc., 2380-116th Ave. N.E., Bellevue, WA 98004
Customer Service Hotline (206)454-7619
CUSTOMER SERVICE CENTERS
3150 Premier Drive, Suite 126, Irving, TX 75063
1777 Phoenix Parkway, Suite 201, Atlanta, GA 30349
3071 - #5 Road, Unit 9, Richmond, B.C. V6X 2T4 Canada
2380-116th Ave. N.E., Bellevue, WA 98004

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